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TEST OF THE MACHINERY OF THE MINNESOTA STEAMSHIP COMPANY'S STEAMER *PENNSYLVANIA.*

BY LIEUTENANTS B. C. BRYAN AND W. W. WHITE, U. S. NAVY.

When one considers the vast amount of capital invested in marine machinery and the immense pecuniary importance attaching to any improvement in design, by means of which even the smallest percentage of reduction in cost per horsepower is permanently effected, the great value of accurate data upon which to base theories for improvements and apply remedies for notable defects, is manifest.

Machinery performance data, to be of any real value, should be secured by expert engineers, and not only must the recorded observations be accurate beyond question, but must also cover such length of time under each phase of conditions as will eliminate any serious defect upon the results which an occasional abnormal datum or personal misreading might otherwise have.

Unfortunately, such accurate data are most difficult to obtain, not only owing to the attendant preparation and expense, but

also to the interference the work creates to the ordinary services of the vessel under observation.

Of late much study has been given to improving the cylinder ratios, reducing the cost of auxiliary machinery by utilizing their exhaust to heat the feed water, and to improvements in methods of stoking; and when occasion was given to obtain general performance data of the large steamer *Pennsylvania*, incident to a test, under the directions of the Bureau of Steam Engineering, of the mechanical stokers installed thereon, every care was taken to include as many as possible bearing on these points.

GENERAL DESCRIPTION.

The vessel, which is of steel throughout, and recently put into active service, was built by the Cleveland Shipbuilding Co. for carrying freight on the Great Lakes. All hull plates are lapped and double riveted along the sides, and treble riveted at the ends; the framing is of channel bars. The upper deck alone extends the entire length of the ship, the interior of the hull being strengthened by longitudinals, beams and partial athwartship bulkheads.

The engine and boilers are placed at the extreme after end of the vessel. One athwartship coal bunker is located immediately forward of the forward boiler-room bulkhead. Quarters for the crew are in the bow, and between these and the forward coal-bunker bulkhead the space is utilized for thirteen large hatches, equally spaced, being provided for ease in loading and discharge.

The principal dimensions of the hull are as follows:

Length between perpendiculars, feet	430
Length over all	450
Beam (moulded), feet	50
Draught (deep), feet	18
Displacement, in tons of 32 cubic feet at 18 feet draught	10,155
Displacement per inch draught (at 14 feet 6 inches draught) in tons of 32 cubic feet	49
Co-efficient of displacement—block	.83
Co-efficient of displacement—midship section	.85
Ratio to rectangle—midship section	.989
L.W.L. co-efficient at 16 feet draught	.899
Double-bottom water-tight compartments	12

ENGINE.

The main propelling engine is of the vertical, direct-acting, inverted, jet-condensing, quadruple-expansion type, designed for a maximum horsepower of about 1,600. One piston valve, actuated by a Joy valve gear, is fitted on the side for each of the high, first and second intermediate-pressure cylinders. The low-pressure valve is a double-ported slide, placed on the after side of the cylinder, and operated by eccentrics and a double-bar Stephenson link. All cylinders are unjacketed.

Cheapness in construction is a chief characteristic in the design of the main engine. The framing and bed plate are of cast iron, and all principal bearings consist of a cast-steel or cast-iron shell lined with white metal. Brass for bearings, or in fact for any purpose, is avoided wherever practicable.

The principal data of the engine are as follows:

Number of cylinders		4
Diameter of cylinders, inches	H.P.	15⅝
	1st I.P.	23¾
	2d I.P.	36½
	L.P.	56
Stroke, inches		40
Diameter of piston valves, inches	H.P. (one)	12
	1st I.P. (one)	16
	2d I.P. (one)	22
Slide valve L.P. double ported, ports 60 inches long by 2¼ inches steam and 4¾ inches exhaust.		
Diameter of piston rods, inches		4¾
Length of connecting rods (between centers), feet		9
Least diameter of connecting rod, inches		5½
Distance between cylinder centers in feet and inches	H.P. to 1st I.P.	3–8
	1st I.P. to 2d I.P.	3–8
	2d I.P. to L.P.	4–9

Order of cylinders from forward: (1) H.P., (2) 1st I.P., (3) 2d I.P., (4) L.P.

Sequence of cranks: H.P., 2d I.P., 1st I.P., L.P.

The H.P. and 1st I.P. are at 180 degrees, as are the 2d I.P. and L.P., the former being at right angles with the latter.

There is a counterbalance on after crank web to balance extra weight of L.P. piston.

The crank shaft is 11 inches in diameter.

Crank pins, 11½ inches in diameter by 11 inches long.

Length of crank-shaft bearings (from forward), 16 inches, 16 inches, 16 inches, 22½ inches and 16 inches.

Thrust bearing, 5 horse shoes; collars on shaft, 19½ inches and 12 inches diameter, 3 inches thick, spaced 5½ inches apart; after end of thrust has line-shaft bearings 11 inches long.

The stern bearing has one lignum vitæ bearing at after end, length, 3 feet 6 inches.

Total length of shafting in vessel, 48 feet 7½ inches.

There is one vertical jet condenser.

BOILERS.

Steam is supplied by two boilers of the Babcock & Wilcox water-tube marine type, built for a pressure of 250 pounds. Each boiler is 9 feet 3 inches long, 12 feet 6 inches wide, and 16 feet 8 inches high, containing 3,000 square feet of heating surface and suitable for 65 square feet of grate surface.

Weight of boilers dry, . . . 145,860 pounds.
Weight of water contained, . . 33,492 pounds.
Total weight of boilers and water, 179,352 pounds.

Each boiler consists of eighteen sections of straight, knobbled charcoal-iron tubes placed at an inclination of 15 degrees with the horizontal, and expanded at their front and back ends into wrought-steel staggered headers. The front headers are connected at their upper ends to a steam and water drum, and at their lower ends to a blow-off connection or mud drum by tubes 4 inches in diameter expanded into bored holes.

All steam-generating tubes are 2 inches in diameter, No. 10 B.W.G. in thickness and 7 feet 3 inches long, the connecting tubes being 4 inches in diameter and No. 6 B.W.G. in thickness. The sides of the boilers are formed by 2-inch tubes inclined the same as the generating tubes, but placed one above the other and expanded into straight manifolds or corner boxes.

The furnace sides are made up of four boxes of 5½ inches square section, pressed from open-hearth steel plate ⅝ inch in

thickness. They are placed at an inclination of 15 degrees, and connected at their ends by means of 4-inch tubes to the corner boxes. These furnace boxes avoid the use of fire-brick side walls, and are of sufficient thickness to withstand the wear and tear of the fire tools. Brick work is used only in forming the bridge walls at the rear of the grate, which wall extends to the height of the lowest row of generating tubes.

All headers and boxes are made of open-hearth steel plate, welded after forming. As the headers are staggered, the tubes are placed in groups of four, each group being covered by a forged-steel elliptical hand-hole plate, into which is welded a stud of 1 inch diameter, the plate being drawn to its seat by a forged-steel bridge and nut, and the joint made on the inside of the header against an elliptical faced seat by a thin lead gasket.

The steam and water drum of each boiler is 42 inches in diameter and 14 feet 10 inches long over the bumped heads. The shell is of open-hearth steel $\frac{19}{32}$ inch in thickness, the heads being $\frac{3}{4}$ inch in thickness. All longitudinal seams are butted and strapped, and have six rows of rivets.

STOKERS AND BLOWER.

Three mechanical underfed stokers* are fitted to each boiler. These were installed by the American Stoker Company, and each consists essentially of a central magazine, a coal hopper, a screw conveyor or worm, a wind box, cast-iron tuyeres or air blocks, and an independent steam motor for driving the conveyor shaft. The rate of feeding coal is controlled by the speed of the motor, which has a reciprocating piston working a crosshead to which is attached suitable link connections operating a rocker arm having a pawl mechanism actuating a ratchet wheel secured to the conveyor shaft.

Coal thrown into the hopper is continually fed by the conveyor or screw into the central magazine of the stoker, being gradually forced upwards, overflowing finally the tuyere blocks. Through these latter air is supplied by a blower, installed for

* A description of this stoker was printed in No. 1, Vol. XI, of the JOURNAL.

the purpose, there being openings towards the central magazine, as well as on the opposite side. The gradual heating of the coal, in its upward course, releases the volatile gases, which are burned by air issuing from the inside of the tuyere blocks. A sort of coke is thus furnished to the dead grates at the sides of the stoker, the air for the combustion of which is supplied by openings on the outside of the tuyere blocks. No air enters from the ash pit.

At the side of each stoker is located a cleaning door. Through these the fires on the dead grates are frequently sliced, and the non-combustible, in the shape of vitrified clinker, periodically removed. These doors provide means, also, of furnishing coal to the furnaces in case of accident to the stoker motors.

The weight of each stoker complete, as fitted on the *Pennsylvania,* is about 3,500 pounds.

Air is supplied to the wind boxes by one Sturtevant blower having a central duct with branches to each stoker. The fan is 60 inches in diameter, 21 inches in width at the periphery, and driven by a two cylinder, simple, double-acting engine, with cranks at 180; the cylinder diameters and stroke are, respectively, 5 and 4 inches. One piston valve controls the admission and emission of steam to both cylinders.

AUXILIARY MACHINERY.*

Number.	Purpose.	Make.	Type.	Diameter of cylinders. H.P.	L.P.	Water.	Stroke.	Reference letter.
1	Main air pump	Blake	Vertical, compound, simplex	7½	12	20	16	A
1	Main feed pump	Blake	Horizontal, compound, duplex, plunger.	6	10	5	10	B
1	Auxiliary feed pump	Deane	Horizontal, duplex, plunger	...	8	4	10	C
1	Bilge pump	Deane	Horizontal, compound	4	7	6	10	D
1	Water-service pump	Deane	Horizontal, compound	4	7	6	10	E
2	Ballast pumps	Deane	Horizontal, compound, duplex	8	12	16	18	F
1	Deck pump (for'd)	Deane	Horizontal, duplex	...	5½	3½	6	G
2	Dynamo engines	Buffalo Forge Co.	Vertical, single-cylinder	...	6	...	6	H
1	Steering engine	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	7	...	7	I
1	Windlass engine (aft)	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	...	...	...	K
1	Capstan engine (for'd)			...	...	...	...	L
5	Deck winches	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	...	...	...	M
1	Blower engine	Sturtevant	Vertical, 2-cylinder	...	5	...	4	N
6	Stoker engines	Amer. Stoker Co.	Horizontal, 1-cylinder	...	6	...	4½	O

*All auxiliary machinery is independent of the main engine.

OBJECT OF THE TESTS.

The tests were made primarily for the purpose of observing generally the practical adaptability and working of underfed stokers (as manufactured and installed by the American Stoker Company) to boilers of sea-going vessels, especially with a view to determining the economic results where (as was the case on the *Pennsylvania*,) an inferior grade of slack coal is used. The particular coal handled on these trials was from the Essen mine in Western Pennsylvania. It contained a large percentage of refuse, and therefore afforded an excellent opportunity of illustrating any superiority in stoking which a mechanical device would give over hand firing. A test of a sample of the coal used gave, by a Mahler bomb calorimeter, 11,790 B.T.U. per pound of dry coal.

Advantage was also taken, as previously noted, of this occasion to ascertain the relative cost of operating all steam machinery installed as an integral or necessary part of the stoker equipment, and to measure the steam consumption of the main engine under various conditions, as well as to determine the economy of several of the independent auxiliaries.

DESCRIPTION OF TESTS.

In all, eight tests of the main engine were made, of which the first five were each of six hours' duration. Those covered by tables No. 1, No. 2 and No. 5 are similar, and representative of the usual power developed under ordinary steaming conditions of the vessel. Test No. 3 was made with almost maximum H.P. cut-off; test No. 4, cutting off very nearly as short as the H.P. valve gear would permit.

Tests on table No. 6 (*a*, *b*, *c*,) of three, two and one hour duration, respectively, were undertaken with the sole aim of ascertaining the economy of the main engine when working under reduced boiler pressures. No account was kept of the coal used.

The economy of the engine, as shown by these tests, is not strictly comparable, one with another, on account of the irregular operation of the air pump, causing, as will be seen from an

inspection of the tables, considerable variation in the vacuum obtained on the different tests. A more satisfactory comparison would have been possible had the vacuum carried been about the same at all times.

Previous to beginning the above tests the dead plates of the furnace fires were thoroughly cleaned of clinker. The same operation was repeated about an hour before each test ended, particular attention being given to have the fires, as nearly as could be judged by the eye, in the same condition at both the beginning and end. Each test was begun and finished with the stoker hoppers entirely filled; coal fired during the interval covered by the test was accurately weighed on a platform scales.

Data of the tests were collected by six observers stationed as follows: Two at main engine indicators; one weighing total feed water pumped to boilers; one weighing condensed exhaust steam from auxiliaries in operation; one collecting engine-room data; one weighing coal and noting fire-room data.

APPARATUS FOR WEIGHING FEED WATER.

During the tests, all water fed to the boilers was delivered by the air pump, through a 5-inch pipe connection to the overboard discharge of the (jet) condenser, into the upper of two tanks in the engine room, which latter were specially installed for the tests. The upper tank was mounted upon platform scales, and water flowing into it could be regulated or shut off, as desired, by means of a valve. Each tank of water, after weighing, was dropped by gravity to the lower tank, from which a suction pipe, of about eight feet in length, led to the feed pump.

Graduated wooden scales were secured between the glands of the boiler water-gage glasses, and the height of water read at the beginning and end, and at hourly periods, as the tests progressed. From an inspection of the tables, it will be observed that a correction (amounting to 192 pounds per inch of height) has been applied for differences of level in order to fix the true weight of water evaporated.

All tests began with the lower or feeding tank full and ended in the same way.

QUALITY OF STEAM

A Barrus throttling calorimeter, attached to the main steam-pipe near the H.P. cylinder, was used to determine the quality of steam supplied by the boilers, and readings of the upper and lower thermometers are recorded in appropriate columns in Tables I–IV. After completing the tests, a calibration of the instrument in port, with fires nearly dead, and steam issuing only through the calorimeter, gave the following:

Upper Thermometer.	Lower Thermometer.	Gage on Engine.
393½	311	240
394	311	240
394	311	241
394¼	311	242
394½	311½	243
395	311½	245
395½	311½	246
396	311½	246
396	312	247
395½	311½	245
394½	311	243
393½	311	240
393	311	238
392	311	...
391	310½	...
390	310	230
389	309¾	...
388	309½	...
387	309¼	...
386	309	217

The moisture in the steam, as figured, after making due allowance for condensation in the instrument, is so infinitesimal as to be entirely negligible in the final results. The assumption has been made, therefore, that dry steam was furnished during all the tests.

METHOD OF AND APPARATUS FOR MEASURING THE STEAM USED BY THE AUXILIARIES.

The method adopted to determine the amount of steam used by the auxiliary machinery was to condense the exhaust steam therefrom and weigh the resultant water. This condensation was accomplished by means of a cylindrical exhaust feed-water heater, of the surface-condenser type, containing thirty-eight 2-inch tubes 9 feet long. The feed water, on its path to the boilers, passed through these tubes and condensed the exhaust steam from the auxiliaries, which was directed into the shell, and at the same time elevated its own temperature proportionally. In order to reduce the temperature during the tests, the drain from the shell of the feed heater was led to a coil contained within a barrel, into which latter a stream of water from the outside ran and overflowed into the bilge. A second barrel, mounted upon platform scales, finally received, by gravity, the condensed exhaust steam of the auxiliaries. As soon as the weighing barrel was filled, the inflow was momentarily stopped, the weight taken, and then the condensed water rapidly discharged into the bilge.

The arrangement of piping was such that the feed could be by-passed around the heater if desired. A communication was also provided for atmospheric exhaust by a suitable connection and valve, fitted between the heater shell and escape pipe.

In touching upon the feed water, it may not be irrelevant to note the course of the feed water after leaving the heater. Instead of being delivered directly therefrom to the boilers, it was led to two horizontal cylindrical purifiers, one for each boiler, situated above and near the back of the latter. These purifiers contained settling pans for the removal of the impurities and scale deposits, and here the feed water was further heated by the ingress of live steam before finally entering the boilers.

STEAM CONSUMPTION OF AUXILIARIES.

On May 28th three tests were run with the view of fixing the steam consumption of the fire-room blower and air pump, and incidentally the total steam necessary to operate the several auxil-

iary pumps and steering engine, which were in use during all the tests. The power developed by the main engine, and the average weight of coal burned, were about as shown in Table I.

An attempt was made to run the different pumps at a constant speed during the entire period covered by the tests, data being recorded at intervals of ten minutes. Only the averages for each test, however, are given in the table below.

Number of test.	Duration of test. Hours.	Boiler pressure. Gage.	Average double strokes per minute.						Temperatures.				Condensed exhaust steam.		Steam used by blower per hour.			Steam used by air pump per hour.		
			Air pump. (*A.*)	Feed pump. (*B.*)	Bilge pump. (*D.*)	Water-service pump. (*E.*)	Auxiliary pump † (*C.*)	Fire-room blower. (*N.*)	Injection.	Hot well.	Feed.	Exhaust water collected.	Total.	Per hour.	By difference.	Correction.	Total.	By difference.	Correction.	Total.
		lbs.											*lbs.*	*lbs.*						
1	1½	240	*	15.2	39.4	16.3	30.6	‡	44	106.2	169	102.5	2042	1361	...	..	...	...	..	...
2	1½	237	*	14	39.7	16.9	24.7	417.4	44	102.3	188.8	98.2	2966	1977	616	62	678	...	..	...
3	1½	235	20.8	15	41.8	16.2	22.6	‡	44	104	186.5	95.9	3022	2015	...	..	...	654	67	721

* Exhausting into main condenser. † Delivering water into barrel containing cooling coil.
‡ Exhausting into atmosphere.

The air-pump piping was so arranged that the exhaust could be thrown either through the feed heater or to the main condenser. Temporary piping and valves were installed to the fire-room blower, by which means it was possible to send the exhaust, as desired, to the feed heater or atmosphere direct.

Test No. 1 shows the steam consumption of the various pumps and steering engine; test No. 2, the same as test No. 1, with the addition of the fire-room blower; test No. 3, the same as test No. 1, with the air pump added. By inspection of tests No. 2 and No. 3 it will be observed that there was a slight variation in the average speed of the different pumps as compared with test No. 1. A correction covering this has, therefore, been applied in order to arrive at the true steam consumption of the blower and air pump.

During the tests here recorded the air pump was not indicated,

but, on May 30th, when working under almost exactly similar conditions, the average of two sets of cards gave the following:

I.H.P. of H.P. cylinder, ...	4.345
I.H.P. of L.P. cylinder, ...	4.323
Total, ...	8.668

Pounds of steam per I.H.P. per hour = 721 ÷ 8.668 = 83.18

From the results of the above tests, and a careful examination of the total and hourly condensed exhaust steam collected and weighed, the speed and auxiliary machinery in use, as shown on Tables I–IV, a close approximation to the average steam consumption per hour of each auxiliary is found to be as follows:

Auxiliary.	Reference letter.	Steam consumption per hour. Pounds.			
		Table I.	Table II.	Table III.	Table IV.
Air pump	*A*	721	715	828	613
Feed pump	*B*	487	468	595	350
Bilge pump	*D*	275	275	320	240
Water-service pump	*E*	146	154	156	150
Auxiliary pump	*C*	330	...	...	...
Starboard dynamo	*H*	...	480	480	...
Port dynamo	*H*	671	...	...	...
Steering engine	*J*	125	125	125	125
Fire-room blower	*N*	622	692	725	550
Total	...	3,377	2,909	3,229	2,028

TEST OF STOKER MOTORS.

To determine the amount of steam used in operating the stokers, the exhaust from one was (May 30, Table II,) led into a barrel containing a previously weighed quantity of water and there condensed. Two tests, similarly made, gave 22.5 and 23.7 pounds respectively, or an average of 23.1 pounds, as the hourly consumption. For all stokers the steam used per hour would, therefore, amount to 138.6 pounds.

The cost of operating all stokers and blower, based on the results of Table II, is found to be 4.29 per cent. of the total steam generated. By reason of the blower exhaust passing through the feed heater, however, the actual net cost of the stoker installation is equivalent only to 1.68 per cent. of the steam made.

ANALYSIS OF FLUE GASES BY PORTABLE ORSAT APPARATUS.

Time.	CO_2.	O.	CO.	Remarks.
	per cent.	*per cent.*	*per cent.*	
		TABLE I. MAY 28TH.		
P. M.				
4.40	8.0	12.0	Nil.	
5.00	8.0	11.6	Nil.	
6.00	7.7	12.3	Nil.	
Averages...	7.9	12.0		
		TABLE II. MAY 30TH.		
P. M.				
4.45	8.2	11.8	Nil.	
4.55	7.5	12.3	Nil.	
5.45	7.8	11.9	Nil.	
6.00	7.3	12.1	Nil.	One minute after slicing.
6.15	8.5	11.3	Nil.	Three minutes after slicing.
6.20	7.3	12.7	Nil.	
7.55	8.0	12.0	Nil.	
8.00	6.5	13.5	Nil.	
Averages...	7.6	12.2		
		TABLE IV. MAY 31ST.		
A. M.				
10.35	5.6	14.0	Nil.	Just before slicing.
10.55	7.1	13.1	Nil.	Just after slicing.
11.10	5.2	15.2	Nil.	Doors open, taking out clinker.
11.40	7.4	11.9	Nil.	Just after slicing.
11.50	7.4	13.2	Nil.	
1.40	6.0	14.2	Nil.	
1.45	7.5	12.5	Nil.	
Averages...	6.6	13.4		
		TABLE V. JUNE 1ST.		
P. M.				
12.55	5.5	14.0	Nil.	
1.00	6.2	13.6	Nil.	
1.05	6.9	13.4	Nil.	
Averages...	6.2	13.7		

Samples for the above tests, as well as the temperature of the escaping gases, as recorded in the tables, were taken near the base of the smoke pipe. The temperature of the gases, just after passing the dampers in the uptakes, showed, on several tests, an average of 75 degrees higher than that indicated at the base of the stack.

PRACTICAL WORKING OF STOKERS.

During the entire trip the stokers worked satisfactorily. The coal, as before stated, was a cheap grade of slack. Fires on the dead grates were sliced at about twenty-minute intervals, at which periods, also, any loose clinker was removed; each fire received a thorough clinkering and cleaning every six hours. The steam required at all times was generated without difficulty and, no doubt, with greater ease and economy than if hand firing had been employed.

Only an extremely light smoke was observable during the ordinary working of the stokers. Practically, it may be said, the coal was burned smokelessly, except when the cleaning doors were opened, either for slicing or clinkering. At such intervals considerable smoke issued from the stack.

A successful trial was made on June 2d with the stokers stopped (blower running), demonstrating the feasibility of feeding the furnaces by hand, coal being supplied through the cleaning doors.

TABLES OF TESTS.

The tables of data of the several tests referred to in this article are placed on the pages immediately following, and are themselves followed by the reproduction of the sample cards and the combined cards. This disposition is made for the greater convenience of studying the results. The general conclusions drawn from the trials tests are appended following the tables.

Variation in vacuum carried on the several trials has already been referred to. The table on opposite page shows the probable increase of power if the air pump had maintained an average vacuum of 26 inches, during the different trials, and the corresponding steam economy of the main engine under these conditions.

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Table showing probable results that would have been obtained on trials with same piston speed and a uniform vacuum of 26 inches.

Number of trial.	Vacuum in inches.		Additional M.E.P. in L.P. cylinder, diff. × .4	Mean revolutions per minute.	Speed of piston per minute.	Additional I.H.P. at 26 inches vac.	Average I.H.P.		Steam used in lbs. per hour by main engine. Trial.	Steam per I.H.P. per hour.			Average boiler pressure.	Cut-off in H.P. cylinder.	Ratio of expansion.
	On trial.	Difference from 26 ins.					On trial.	At 26 inches vacuum.		On trial.	At 26 inches vacuum.	Difference in lbs.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	24.35	1.65	.660	77.33	515.53	25.30	1,206.71	1,232.01	17,252	14.30	14.00	.30	242	.644	17.95
2	23.56	2.44	.966	74.45	496.33	35.65	1,169.77	1,205.42	16,694	14.27	13.84	.43	244	.658	17.64
3	22.73	3.27	1.308	79.44	529.60	51.51	1,455.04	1,506.55	20,952	14.40	13.91	.49	241	.798	15.50
4	22.71	3.29	1.316	66.31	442.07	43.26	862.78	906.04	12,725	14.75	14.04	.71	245	.542	20.60
5	23.67	2.33	.932	73.74	491.60	34.07	1,168.88	1,202.95	16,697	14.28	13.98	.30	245	.656	17.77
6*a*	23.40	2.60	1.040	67.10	447.33	34.58	855.87	890.45	12,939	15.12	14.54	.58	197	.656	17.77
6*b*	21.60	4.40	1.760	51.02	340.13	44.51	394.94	439.45	6,815	17.26	15.51	1.75	130	.656	17.77
6*c*	21.16	4.84	1.936	44.93	299.53	43.12	264.89	308.01	5,305	20.02	17.22	2.80	108	.656	17.77

Column 4 is based on the assumption that an increase in vacuum would have produced an increase in the M.E.P. on the L.P. piston of 80 per cent. of its equivalent pressure. One inch of vacuum being .491 lb. pressure, there follows an increase of .491 × .8 = .3928 or about .4 lb. M.E.P. for every inch of vacuum.

Column 16. Ratio of the volume of the L.P. cylinder, including its clearance, to the volume of the H.P. cylinder, including its clearance, up to the point of cut-off.

TABLE I. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Duration of test, 6 hours.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room.
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	Heights of water in boiler waterspaces.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
p. m.																						*P. S.*
2·30	241	97	33	5.50	24.25	69063	...	21	14.5	19	28	34	380	...	45	103	210	392	310	...	...	4½
3·00	237	95	32	5.00	24.25	71410	78.0	22	15	16	51	31	390	...	45	99	206	392	310	...	...	..
3·30	240	97	33	5.50	24.25	73746	77.9	23.5	14.5	19	29	29	382	...	45	100	211	392	310	...	...	3½
4·00	240	97	33	5.50	24.25	76070	77.5	22	16	18	29	29	384	...	45	98	211	392	310	...	...	..
4·30	240	97	33	5.50	24.25	78406	77.7	20.5	15	18	28	29	382	...	45	97	214	392	310	...	...	4½
5·00	236	95	32	5.50	24.50	80730	77.5	21	13	18	40	29	392	...	45	97	210	390	311	...	...	..
5·30	236	97	33	5.50	24.50	83040	77.0	21	14	18	48	32	392	...	42	97	210	391	311	...	...	3½
6·00	235	94	32	5.50	24.50	85343	76.9	10	14	17	42	28	360	...	43	96	219	389	310	...	...	..
6·30	248	97	33	5.50	24.50	87655	77.1	17	13	17	50	26	360	416	44	98	234	...	...	39.5	99.5	5
7·00	238	96	32	5.25	24.50	89990	77.8	15	15	15	50	26	400	426	44	102	239	...	...	38.5	98.5	...
7·30	240	96	32.5	5.50	24.50	92321	77.7	11	14	14	48	27	380	422	45	102	235	...	...	38.5	97.5	4½
8·00	241	97	33	5.50	24.50	94645	77.5	11.5	16.5	14	46	26	380	418	45	103	241	...	...	37.5	96.5	...
8·30	240	93	31	5.25	23.75	96900	75.2	6	13	15	50	23	392	424	45	102	245	...	...	37.5	97.0	4
Total.....	3112	1251	422.5	70.50	316 50	...	...	221.5	187.5	218	539	369	4974	2106	578	1291	2885	3130	2482	191.5	489	..
Average....	239.4	96 2	32.5	5.42	24.35	...	...	17.0	14.4	16.8	41.5	28.4	382.6	421.2	44.5	99.3	222.0	391.3	310.3	38.3	97.8	..

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .644; first I.P. = .624; second I.P. = .668; L.P. = .642.

Indicator cards from the main engines were taken at half-hourly intervals, beginning at 2·30 P. M., and ending at 8 P. M.

The condition of fires under boilers at end of test was greatly different from that at beginning. An allowance has been made for this as nearly as possible, but the total weight of coal and ash for the test, as recorded in the table, is not considered altogether reliable.

The following auxiliaries were in operation during this test (for reference see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); auxiliary (*C*) pump for the purpose of delivering water into the barrel containing cooling coil; bilge (*D*) and water service (*E*) pumps; fire-room blower (*N*) and steering (*J*) engine. One dynamo engine (*H*) was started at 5·48 P. M., and continued in operation until end of test. The exhaust from these auxiliaries after passing through the feed heater, was collected, and the hourly and total results are tabulated in columns 27 and 28.

COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 28, 1899.

Draught, forward, 2 feet 2 inches; aft, 13 feet 5 inches. Speed, 13.3 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Tempera-tures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage.		Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
	Per hour.	Total																		
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	246	2 8	.32	104	450	...	...
...	...	...	...	...	107.5	47.50	18.62	7.625	315.02	324.95	304.38	294.86	1239.21	245	2 4	.32	106	440	...	...
1041	20289	20289	2738	2738	106	47.00	18.00	7.375	310.23	321.12	293.87	284.83	1210.05	240	2 7/16	.32	104	435	...	...
...	...	...	...	...	105	46.75	18.50	7.250	305.72	317.77	300 48	278.56	1202.53	245	2 8	.33	104	440	...	...
1060	19972	40261	2720	5458	108	47.50	18.70	7.365	315.27	323.70	304 51	284.10	1227 58	244	2 1/16	.30	106	440	...	...
...	...	...	...	...	106	47.00	18.80	7.080	308.64	319.47	305.35	272.03	1205.49	240	2 1/16	.31	106	460	...	...
1030	20622	60883	2730	8188	106.5	47.00	18.50	7.250	308.10	317.41	298.54	277.41	1201.46	240	2 7/16	.31	106	440	...	...
...	...	...	...	...	107	46.75	18.55	7.210	309.13	315.32	298.96	274.90	1198.31	237	2	.33	104	439	...	...
1430	20382	81265	3110	11298	103	45.50	17.88	6.630	298.35	307.67	288.91	253.42	1148.35	246	2 1/4	.33	104	440	...	...
...	...	...	...	...	108.5	47.50	19.10	7.130	317 14	324.11	311.42	275.02	1227.69	250	2 8	.30	106	440	...	...
1284	20680	101945	3449	14747	108	46.50	19.10	7.400	315.27	318.58	311.02	285.06	1229.93	240	2 7/16	.26	104	440	...	...
...	...	...	...	...	108	45.50	18.50	7.080	314.46	309.34	300.47	272.03	1196.30	242	2 8	.26	104	450	...	...
1446	20494	122439	3351	18098	111	47.50	18.88	7.220	313.60	313.29	297.55	269.18	1193.62	230	2 8	.26	106	440	...	...
...	...	...	...	...	1284.5	562.00	223.13	86.615	3730.93	3812.73	3615.46	3221.40	14480.5	3145	33	3.95	1364	5754	14400	2183
...	...	...	...	...	107.04	46.85	18.59	7.22	310.91	317.73	301.29	276.78	1206.71	242	2.54	.304	104.9	442.7	...	...

Coal was fed to the boilers by six stoker (*O*) engines which exhausted into the ash pits.

Valves in the auxiliary, steam and exhaust line of piping leading to machinery forward of the boiler-room bulkhead were closed during the test, as was also the valve in the piping which makes connection between the shell of the feed heater and the escape pipe.

A very slight escape was noticed about whistle and valve. The weather became foggy, and whistle was blown at about one and one-half-minute intervals from 6·48 until end of test.

This test was made on the up-trip of the vessel without cargo, as will be observed from the draught, but with water ballast in the double bottom compartments.

TABLE II. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

	Engine-room																				
	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		
Time.	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	Height of water in boiler water gages. Inches.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
P. m.																						*P. S.*
2·00	235	94	31.5	5.00	24.25	11489	...	18	15	18	47	*	426	...	45	104	192	391	310	...	†	4½
2·30	245	97	33	5.50	23.00	13732	74.8	19	16	18	44	*	434	...	45	115	204	394	312	...	†	...
3·00	243	97	33	5.50	23.50	15983	75.0	23	15	19	45	*	450	...	45	106	214	395	312	...	†	4 -5½
3·30	244	97	33	5.50	23.50	18224	74.7	24	15	18	45	*	390	...	45	108	211	392	311	...	†	...
4·00	239	96	32.5	5.25	23.50	20473	75.0	24.5	15	18	46	*	440	...	45	108	212	392	311	...	†	7 -8½
4·30	237	95	32	5.00	23.50	22695	74.1	23	15	18	30	*	441	...	44	105	206	390	311	...	†	...
5·00	240	96	32.5	5.25	23.50	24930	74.5	24	14	18	30	*	434	...	45	106	214	394	312	...	†	3½-5½
5·30	241	97	32.5	5.25	23.50	27171	74.7	24.5	17	18	39	*	442	...	45	105	212	394	311	...	†	...
6·00	223	90	30	4.75	23.75	29389	73.9	8	13	15	38	*	418	...	43	103	200	387	309	...	†	6 -6
6·30	242	97	32.5	5.25	23.50	31615	74.2	22	13	18	37	*	424	...	43	106	220	393	312	...	†	...
7·00	237	96	32.5	5.25	23.50	33861	74.9	19	15	18	35	*	420	440	44	105	224	...	...	25	†	3 -4
7·30	225	90	30	4.50	23.75	36095	74.1	20	14	18	49	*	418	452	44	100	228	...	...	36.5	†	...
8·00	244	97	33	5.50	23.50	38292	73.2	17	14	17	55	*	398	450	45	103	234	...	...	36 5	†	6½-3½
Total.....	3095	1239	418	6750	306 25	...	...	266	191	231	540	...	5535	1342	578	1374	2771	3922	3111	98	...	...
Average....	238.1	95 3	32.15	5.19	23.56	...	...	20.46	14.7	17.8	41.5	...	425.8	447.3	44.5	105.7	213.2	392.2	311.1	32.7	...	...

* Not in operation.

† Voltmeter out of order.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .658; first I.P. = .627; second I.P. = .682; L.P. = .636.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge pump (*D*) and water service pumps (*E*); fire-room blower (*N*) and steering (*J*) engine. One dynamo engine (*H*) was started at 6·54 P. M., and continued in operation until end of test.

COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 30, 1899.

Speed, 11.2 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Tempera-tures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage.		Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
	Per hour.	Total																		
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	106	47.00	18.75	7.210	297.88	308.34	293.92	267.38	1167.52	241	2⅞	.33	90	425	...	...
...	...	...	...	...	108.5	47.50	19.00	7.500	305.96	311.62	297.85	278.13	1193.56	248	3¼	.32	90	430	...	...
20122	19666	19666	2360	2360	107.5	47.50	19.00	7 380	302.93	312.45	298.64	274.42	1188.44	245	3	.31	90	445	...	...
...	...	...	...	...	112	48.75	19.00	7.250	314.33	319.40	297.45	268.51	1199.69	250	2¼	.28	93	420	...	...
19336	19324	38990	2436	4796	110	46.75	18.50	7.37	309.95	307 51	290.78	274.05	1182.29	248	2⅞	.32	87	410	...	...
...	...	...	...	...	110	46.75	18.50	7.250	306.23	303.83	287.30	266.34	1163.70	250	3	.33	88	410	...	...
18841	19009	57999	2442	7238	112	48.00	19 25	7.500	313 49	313.64	300.56	277.02	1204.71	247	3	.33	87	425	...	...
...	...	...	...	...	109	46.75	18.50	7.350	305.91	306.28	289.62	272.21	1174.02	245	3⅛	.32	85	425	...	...
19300	19724	77723	2497	9735	104.5	44.50	18.00	6.875	290.13	288.42	278.77	251.88	1109 20	237	3	.31	89	410	...	...
...	...	...	...	...	107	45.75	18.50	7.375	298.28	297.73	287.68	271.30	1154.99	245	3⅛	.31	88	415	...	...
18350	19010	96733	2560	12295	107	46.00	18.50	7.50	301.09	302.18	290.39	278.50	1172.16	250	3¼	.33	88	430	...	...
...	...	...	...	...	107.5	45.50	18.50	7.000	299.27	289.21	287.29	257.16	1132.93	225	3⅛	.32	80	460	...	...
19931	19403	116136	2842	15137	108.5	47.00	19.00	7.500	298.39	301.74	291.47	272.18	1163.78	243	2⅞	.32	82	430	...	...
...	...	...	...	...	1409.5	607.75	243.00	95.66	3943.84	3962.35	3791.72	3509.08	15206.99	3174	38⅛	4.13	1137	5535	14200	2575
...	...	...	...	...	108.42	46.75	18.69	7.312	303.37	304.80	291.67	269.93	1169.77	244 2	2.99	318	87.5	425.8	...	...

Valves in auxiliary piping were arranged, and exhaust from auxiliaries in operation collected and weighed, as stated in Table I.

A very slight escape of steam was noticed about whistle and valve.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

TABLE III. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room
Time.	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	Heights of water in boiler water gages, Inches.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
p. m.																						P.S.
8·00	244	97	33	5.50	23.50	38292	...	17	14	17	55	...	398	450	45	103	234	...	...	36.5	†	6½
8·30	236	91	35	8.00	23.00	40626	77.8	21	18	18	57	...	440	446	44	109	219	...	...	36	†	..
9·00	232	91	34	7.50	21.00	43002	79.2	21	18	18	31	...	454	444	44	110	204	...	...	36	†	3
9·30	245	94	34	7.00	23.00	45398	79.9	12	16	18	43	*	450	446	44	105	240	...	...	35	†	..
10·00	235	92	32	6.00	23.25	47782	79.5	21	16	18	48	...	460	450	44	106	210	...	...	34	†	3
10·30	225	89	31	5.50	23.00	50108	77.5	22	16	19	50	...	448	450	44	104	220	...	...	34	†	..
11·00	240	95	33	5.50	23 00	52466	78.6	26	16	18	50	...	438	448	43	110	211	...	...	34	†	8¼
11·30	245	97	35	7.00	22.75	54897	81.0	26	18	18	52	...	456	446	43	114	217	394	312	34	†	..
12·00	240	94	33	7.00	23.00	57347	81.7	25	20	18	46	...	458	446	44	112	218	395	312	36	†	3
a. m.																						
12·30	246	94	32	6.50	23 00	59780	81.1	20	17	18	48	...	464	442	43	109	218	391	311	36	†	..
1·00	230	91	31	5.50	23.00	62164	79.5	19	16	18	49	...	454	446	43	106	209	386	310	35	†	3
1·30	225	89	31	5.25	21.50	64504	78.0	20	18	18	48	...	446	448	44	110	223	394	311	34	†	..
2·00	240	91	34	6.50	22.50	66890	79.5	25	18	18	51	...	440	446	44	104	224	...	...	34	†	3
Total.....	3083	1205	428	82.75	295.50	...	...	275	221	234	628	...	5806	5808	569	1402	2847	1960	1556	454.5	...	..
Average....	237.2	92 7	32.9	6.36	22.73	...	...	21.2	17	18	48.3	...	446.6	446.8	43.8	107.8	219	392	311.2	34.9	...	..

* In operation about 15 minutes between 9 and 10 P. M.

† Voltmeter out of order.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .798; first I.P. = .797; second I.P. = .802; L.P. = .746.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge pump (*D*) and water-service pumps (*E*); fire-room blower (*N*) and steering engine (*J*) and one dynamo engine (*H*).

COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 30, 31, 1899.

Speed, 11.4 miles.

data.																Fire-room data.						
Feed water.				Water from auxil's.		Mean effective pressures.				I.H.P.						Pressures.			Tempera-tures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage			Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.		Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
	Per hour.	Total																				
24	25	26		27	28	29	30	31	32	33	34	35	36	37		38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																				
...	...	...		...	...	...	...	...	...	...	...	...	...	...		243	2⅞	.32	82	430	...	...
...	...	...		...	...	125	55.0	20.25	10.25	365.37	375.43	330.18	395.35	1466.33		237	...	.33	78	425	...	...
22831	23551	23551		3158	3158	126	57.0	20.75	10 00	374.91	395.99	344.42	392.66	1507.98		240	2⅞	.33	79	460	...	...
...	...	...		...	...	128	56.5	20.25	8 90	384.24	395.99	339.09	351.75	1471.07		250	3⅛	.33	76	460	...	...
25902	25134	48685		3244	6402	121	53.0	19.50	8.25	361.41	369.61	324.89	325.17	1381.08		240	...	.34	86	450	...	...
...	...	...		...	...	121	53 5	20.00	8.25	352.31	363.70	317.45	316.98	1350.44		228	3⅛	.35	94	450	...	...
23600	23140	71825		3064	9466	129	58.0	20.25	9.00	380.94	399.89	333.57	350.71	1465.11		244	3⅛	.35	86	460	...	...
...	...	...		...	...	129	57.0	20.75	9.50	392.57	404.99	352.25	361.42	1511.23		251	3⅛	.35	86	450	...	...
24604	24988	96813		3315	12781	129	57.0	20.00	9.00	395.95	408 49	342.44	364.54	1511.42		245	3⅛	.32	93	500	...	...
...	...	...		...	...	127	55.0	20.25	8.75	386.95	391.21	344.18	351.89	1474.16		239	3⅛	.33	95	480	...	...
24860	25244	122057		3171	15952	120	55.5	19 25	8.60	358.42	387.04	320.73	338.96	1405.15		237	3⅛	.33	94	480	...	...
...	...	...		...	...	128	57.5	20.25	9.00	378.70	397.19	334.21	351.38	1461.48		230	3	.33	94	520	...	...
23648	24032	146089		3161	19113	...	...	...	...	...	...	...	...	...		246	3⅛	.33	...	480	...	...
...	...	...		..	...	1383	6150	221.50	9900	4131.77	4289.53	3683.41	3900.74	16005.45		3130	33⅛	424	1043	6045	18000	3800
...	...	...		...	...	125.7	55.9	20.13	9.00	375.62	389.96	334.85	354.61	1455.04		240 8	2.61	326	86.9	465	...	...

Bilge pump out of operation for 6 minutes, from 8·15 P. M. Fire-room blower exhausting into atmosphere (average revolutions 450) for 36 minutes, from 9·14 P. M.

Valves in auxiliary piping were arranged, exhaust from auxiliaries in operation collected and weighed, and escape of steam about whistle and valve, as noted in Table I.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

TABLE IV. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Duration of test, 6 hours. Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

	Engine-room																				
	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		
Time.	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Ampères.	Volts.	Height of water in boiler water gages. Inches.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a. m.																						*P. S.*
10·00	248	97.5	34	4.50	23.50	98700	...	19	10.5	18	25	*	340	*	42	109	222	...	...	†	†	6 -$\frac{5}{8}$
10·30	242	96	33	5.00	23.00	709	67.0	17.5	11	18	40	*	334	*	43	116	220	395	311	†	†	..
11·00	243	96	33	5.00	23.00	2717	66.9	21	12	18	40	*	290	*	44	117	222	395	312	†	†	4$\frac{1}{2}$-6
11·30	243	96	33	4.75	22.75	4707	66.3	21.5	12	18	43	*	276	*	45	114	218	394	311	†	†	..
12·00	243	96	33	5.00	22.50	6700	66.4	19 5	12	17	38	*	340	*	44	115	225	394	311	†	†	6$\frac{1}{2}$-5
p. m.																						
12·30	225	89	31	4.00	22.50	8684	66.1	22	9	18	32	*	316	*	45	115	234	386	310	†	†	..
1·00	231	91	31	4.00	23 00	10605	64.0	13	12	18	36	*	364	*	45	116	220	390	310	†	†	7 -$\frac{1}{2}$
1·30	250	99	34	5.00	22.50	12573	65.6	16	11	17	32	*	376	*	45	117	232	396	311	†	†	..
2·00	244	96	33	4.75	22.50	14552	66.0	19	11.5	16	36	*	384	*	45	116	228	395	311	†	†	4$\frac{1}{2}$-7
2·30	241	95	33	4.75	22.50	16534	66.1	18	12	17	37	*	334	*	45	115	232	...	...	†	†	..
3·00	250	99	34	5.25	22.50	18543	67.0	20.5	12	17	36	*	354	*	45	116	234	...	...	†	†	4$\frac{1}{2}$-5$\frac{1}{2}$
3·30	244	96	34	5.25	22.50	20552	67.0	18	11	17	37	*	352	*	45	115	228	...	...	†	†	..
4·00	240	99	34	5.00	22.50	22571	67.3	18	13	18	39	*	344	*	45	118	230	...	...	†	†	5$\frac{1}{2}$-6
Total	3144	1245.5	430	62.25	295 25	...	...	243	149	227	471	...	4404	...	578	1499	2945	3145	2487	...	...	..
Average...	241.8	95 8	33.1	4.79	22.71	...	...	18.7	11.5	17.5	36.2	...	338.8	...	44 5	115.3	226.5	393 1	310.9	...	...	..

* Not in operation.

† Dynamo not in use.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .542; first I.P. = .528; second I.P. = .570; L.P. = .560.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pump (*B*); bilge pump (*D*) and water-service pump(*E*); fire-room blower (*N*) and steering engine (*J*).

COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 31, 1899.

Speed, 9.8 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage		Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
	Per hour.	Total																		
21	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	lbs.	lbs.	...	...	...	...	...	...	...	...	...	...	...	250	$1\frac{0}{16}$	.32	...	420	...	...
...	...	...	...	...	94	37.50	17.25	5.80	236.62	220.36	242.21	192.66	891.85	247	$1\frac{2}{16}$	.32	...	435	...	...
15932	15158	15158	2068	2068	91	37.50	16.50	5.75	228.72	220.03	231.34	190.72	870.81	247	$1\frac{1}{16}$	.32	...	420	...	...
...	...	...	...	...	92	37.50	16.25	5 80	229.16	218.05	225.81	190.65	863.67	246	$1\frac{3}{16}$	.36	82	430	...	...
15472	15166	30324	2035	4103	93	36.75	16 75	5.60	232 00	214.02	233.09	190.93	870.04	245	$1\frac{0}{16}$	.31	82	400	...	...
...	...	...	...	...	90	36 00	16.50	5.50	223.50	208.71	228 57	180.24	841.02	230	$1\frac{2}{16}$	.31	76	405	...	...
14926	14380	44704	2000	6103	89	36.00	16 50	5.40	214.00	202.07	221.31	171.34	808.72	235	$2\frac{1}{16}$	.30	92	435	...	...
...	...	...	...	...	91	37.50	17.00	5.60	224.27	215.75	233.72	182.09	855.83	252	$2\frac{1}{16}$	.34	75	450	...	...
14281	14743	59447	2099	8202	93	37.50	16.50	5.75	230.60	217.07	228.22	188.14	864.03	248	$2\frac{1}{16}$	.32	76	450	...	...
...	...	...	...	...	91.5	36.00	16.75	5.70	227.23	208.61	232.03	186.79	854.66	248	2	.32	77	430	...	...
14697	15215	74662	2070	10272	94	36.00	16.75	5.75	236.61	211.54	235.19	191.00	874.34	250	2	.32	78	420	...	...
...	...	...	...	...	92	37.00	16.75	5.80	231.58	217.42	235.19	192.66	876.85	246	$1\frac{7}{16}$	.32	84	440	...	...
15066	14904	89566	2111	12383	93	37.00	16.50	5.85	235 14	218.40	232.72	195.20	881.46	245	$1\frac{5}{16}$	.32	85	440	...	...
...	...	...	...	...	1103.5	442.25	200.00	68.30	2749.43	2572.03	2779.40	2252.42	10353.28	3189	$23\frac{7}{16}$	418	807	5575	11800	2463
...	...	...	...	...	91.96	36.85	16.67	5.70	229.12	214.34	231.62	187.70	862.78	245 3	1.84	322	80.7	428.9	...	...

A leak around gland of one plunger of water cylinder of feed pump was detected during the test, the water from which was collected and amounted to 66 pounds per hour. Columns 25 and 26 have been corrected for this leak.

Valves in auxiliary piping were arranged, escape of steam about whistle and valve, and exhaust from auxiliaries in operation collected and weighed, as noted in Table I.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

TABLE V. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room	
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Ampères.	Volts.	Heights of water in boiler gages. Inches.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
a. m.																						*P. S.*	*lbs.*
9·00	240	97	33	6	24.00	63507	...	*	†	†	†	‡	410	‡	45	...	181	†	†	...	...	...	...
9·30	245	98	33·5	6	24.00	65699	73.1	*	†	†	†	‡	396	‡	45	...	176	†	†	...	...	...	...
10·00	244	98	33 5	6	24.00	67908	...	*	†	†	†	‡	408	‡	45	101	181	†	†	...	...	4 -5	...
10·30	232	94	32	5.50	24.00	70123	73.7	*	†	†	†	‡	370	‡	45	102	182	†	†	...	...	...	...
11·00	240	96	32.5	6	24.00	72325	...	*	†	†	†	‡	390	‡	43	100	180	†	†	...	...	...	20077
11·30	245	98	33·5	6	24.00	74547	73·7	*	†	†	†	‡	440	‡	43	102	182	†	†	...	...	...	...
12·00	242	97	33	6	24 00	76767	...	*	†	†	†	‡	438	‡	43	102	184	†	†	...	...	4½-6½	19372
p. m.																							
12·30	245	98	34	6	24.00	78988	74.0	*	†	†	†	‡	410	‡	43	103	170	†	†	...	...	...	...
1·00	235	95	32.5	5.75	24.00	81212	...	*	†	†	†	‡	400	‡	43	102	186	†	†	...	...	5½-5	19017
1·30	248	100	35	6.25	23 00	83430	74.0	*	†	†	†	‡	390	‡	43	103	184	†	†	...	...	...	...
2·00	245	98	34	6.25	23.00	85653	...	*	†	†	†	‡	410	‡	46	106	184	†	†	...	...	4½-7½	20570
2·30	241	96	33	6	22.75	87828	73·3	*	†	†	†	‡	400	‡	46	107	184	†	†	...	...	...	...
3·00	242	97	32.5	6	23.00	90052	...	*	†	†	†	‡	398	‡	46	107	186	†	†	...	...	5½-6½	19614
Total	3144	1262	432	77.75	307.75	...	...	...	...	...	...	...	5260	...	576	1135	2360	...	...	...	...	...	...
Average ..	241.8	97.1	33·5	5.98	23.67	...	...	...	...	...	...	...	404.6	...	44·3	103.2	181.5	...	...	...	...	...	...

* Not taken. Exhausting into main condenser.
† Not taken.
‡ Not in operation.
§ Not weighed.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .656; first I.P. = .658; second I.P. = .690; L.P. = .656.

The object of this test was to determine the economic evaporation of the boilers when working with dampers in uptake about one-half closed. As no observable difference developed between this and other tests, the dampers (at 11 A. M.) were opened wide, as in previous tests. The total water fed to the boilers was not weighed during the first hour of test.

COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE HURON. JUNE 1, 1899.

Duration of test, 6 hours.

data.																Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage		Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
	Per hour.	Total																		
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	†	...	...	†	450	...	...
...	...	...	...	...	108	46.50	18.50	7.20	296.61	298.12	283.42	260.94	1139.09	†	...	...	†	460	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	†	2¾	.18	†	480	...	...
...	...	...	...	...	106	45.50	18.00	7.30	293.51	294.11	278.02	266.73	1132.37	†	2¾	.17	†	480	...	...
20077	...	...	...	...	...	...	...	...	...	...	...	...	...	†	2¾	.18	†	440	...	...
...	...	...	...	...	109	48.00	18.75	7.50	301 67	310.27	289.61	274.04	1175.59	†	2¾	.31	†	460	...	...
19372	...	...	...	...	...	...	...	...	...	...	...	...	...	†	3	.31	†	470	...	...
...	...	...	...	...	109	47 50	19.00	7.38	303.04	308.18	294.66	270.75	1176.63	†	2¾	.31	†	480	...	...
19017	...	...	...	...	...	...	...	...	...	...	...	...	...	†	2¾	.31	†	460	...	...
...	...	...	...	...	113	48.50	19.50	7.80	314 16	314.78	302.41	286.16	1217.51	†	2¾	.30	†	460	...	...
20570	...	...	...	...	...	...	...	...	...	...	...	...	...	†	2¾	.29	†	450	...	...
...	...	...	...	...	108	46.50	19.50	7.60	297.41	298.93	299.55	276.18	1172.07	†	2¾	.30	†	460	...	...
19614	...	98026	...	...	...	...	...	...	...	...	...	...	...	†	3	.30	†	470	...	...
...	...	...	...	...	653	282.50	113.25	44.78	1806.40	1824.39	1747.67	1634.80	7013.26	...	30¾	2.96	...	6020	14750	...
...	...	...	...	...	108.83	47.08	18.875	7.46	301.07	304.06	291.28	272.47	1168.88	245	2.795	.27	...	463.1	...	...

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge (*D*) and water-service pumps (*E*); fire-room blower (*N*) and steering engine (*J*). All auxiliaries exhausting into feed heater except air pump. Condensed exhaust steam from auxiliaries was not weighed.

Valves in auxiliary piping were arranged, escape of steam about whistle and valve was the same as noted in Table II.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to boilers by six stoker (*O*) engines, which exhausted into the ash pits.

TABLE VI.

LOG OF TEST OF ENGINES OF MINNESOTA STEAMSHIP COMPANY'S

Draught, forward, 17 feet 2 inches.

	Time.	Steam pressures. At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Main engine. Counter.	Revolutions per minute.	Mean effective pressure. H.P.	First I.P.	Second I.P.	L.P.	I.H.P. H.P.	First I.P.	Second I.P.	L.P.	Total.	Temperatures. Injection.	Hot well.	Feed.	Height of water in boiler water glasses. Inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Test A.	*p.m.*																				P. S.
	4·00	195	77	26	2.25	23.50	94140	67.1	90.	39.00	15.50	5.75	224.80	229.51	217.96	191.27	863.54	44	97	194	5¼–4½
	4·30	195	78	26	2.25	23.25	96139	66.6	90.	39.00	15.88	5.75	225.19	227.86	221.64	189.42	864.11	43	95	187	...
	5·00	191	76	25.5	2.00	23.25	98152	67.1	88	38.00	15.25	5 64	221.84	223.63	214.45	187.52	847.44	44	98	202	5¼–4½
	5·30	197	79	26.5	2.375	23.50	174	67.4	91	39 50	15.75	5.75	230.43	233.50	222.47	192.14	878.54	43	97	201	...
	6·00	195	78	26	2.25	23.50	2202	67.6	91	39.25	15.00	5.75	231.11	232.71	213 22	192.71	869.75	43	97	202	3¼–5½
	6·30	190	75	25	2.00	23.50	4215	67.1	86	37.50	15.13	5.50	216.80	220.69	212.76	182.97	833.22	43	95	210	...
	7·00	191	76	25.25	2.00	23.50	6218	66 8	86	37.50	15.13	5.50	215.83	219.71	216.75	182.15	834.44	43	95	205	5¼–4
	Tot'l	1354	539	180.25	15.125	164.00	...	...	622	269.75	107.64	39.64	1566.00	1587.61	1519.25	1318.18	5991.04	303	674	1401	...
	Av'g	193.4	77	25.77	2.17	23.4	...	67.1	88.86	38.54	15.38	5.66	223.72	226.80	217.04	188.31	855.87	43.3	96.3	200.1	...
Test B.	*p.m.*																				
	8·00	127	47	15.00	*	21.50	9857	51.0	58.5	23.0	9.25	3.10	112.08	102.83	98.87	78.38	392.16	44	82	224	8 –8½
	8·30	120	43.5	14 00	*	21.50	11394	51.2	58.0	24.0	9.00	2 50	111.57	107.77	96.57	63.46	379.37	44	80	224	...
	9·00	122	44	13.75	*	22.00	12895	50.0	59.0	24.0	9.00	2.75	110.83	105.25	94.31	68.17	378.56	47	102	208	4 –7½
	9·30	135	50	15.50	*	21.50	14442	51.6	64.0	27.0	9 25	3.25	124.07	122.20	102.33	83 14	431.74	49	110	212	...
	10·00	125	45	14 50	*	21.50	15980	51.3	59.5	24.5	9.00	2.80	114.68	110.23	96.76	71.21	392.88	...	...	...	2 –7
	Tot'l	629	229.5	72.75	*	108.00	...	...	299	122.5	45 50	14.40	573.23	548.28	488.84	364.36	1974.71	184	374	868	...
	Av'g	125 8	45.9	14.55	*	21.60	...	51.02	59.8	24.5	9.10	2.88	114.65	109.65	97.77	72.87	394.94	46	93.5	2.17	...
Test C.	*p.m.*																				
	10·30	112	40	12.25	*	21.50	17397	45.	52.5	21.50	6.13	2.25	88.76	84.85	57.81	50.21	281.63	55	101	220	6¼–7½
	11·00	100	35	11.25	*	21.00	18788	46.4	47.5	19.75	5.75	2.00	82.86	80.38	55.92	46.01	265.17	56	100	216	...
	11·30	101	35	11.00	*	21.00	20093	43.5	48.5	19.75	5.50	2.00	79.26	75.35	50.14	43.14	247.89	56	100	218	5¼–9
	Tot'l	313	110	34.50	...	63.50	...	...	148.5	61.00	17.38	6.25	250.88	240.58	163.87	139 36	794 69	167	301	654	...
	Av'g	104.3	36.66	11.50	...	21.16	...	...	49.5	20.33	5.79	2.08	83.63	80.19	54.62	46.45	264.89	55.7	100.3	2.18	...

* Pressure less than atmospheric—not indicated on gage.

‡ Not in use.

† Cylinder cut-offs and opening of throttle valve during the above tests, the same as noted in Table V.

STEAMER *PENNSYLVANIA*, AT REDUCED STEAM PRESSURE. JUNE 1, 1899.

Draught, aft, 17 feet 6 inches.

Heights of water in boiler water glasses. Inches.	Feed water.			Water from auxiliaries.		Air pump.				Remarks.
	As weighed per hr.	Corrected for height in boiler water gages.		Pounds per hour.	Pounds total.	Double stroke.	I.H.P.			
		Per Hr.	Total.				H.P.	L.P.	Total.	
21	22	23	24	25	26	27	28	29	30	
P. S.										
5½-4½	...	...	...	...	...	...	...	...	...	Auxiliary machinery in operation as follows: Feed (*B*), bilge (*D*) and water service (*E*) pumps, blower (*N*) and steering engine (*J*). Dynamo was started at 6·13 P. M. Condensed exhaust steam from these collected and weight recorded in columns 25 and 26. Air pumps would not work satisfactorily, exhausting into feed heater, on account of reduced steam and excessive back pressure; exhaust was, therefore, sent to main condenser.
...	...	...	...	...	...	...	...	...	...	
5½-4½	15063	14943	14943	1499	1499	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	
3½-5½	15050	15266	30209	1525	3024	22	3.80	3.565	7.365	
...	...	...	...	...	...	...	...	...	...	
5½-4	15776	15728	45937	1841	4865	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	
...	15296	15312	...	1622	...	...	...	...	...	
8 -8½	...	...	...	...	...	23	...	6.914	...	Weight of condensed exhaust steam, recorded in columns 25 and 26, is from the following auxiliary machinery: Feed (*B*), bilge (*D*) and water service (*E*) pumps, dynamo (*H*), blower (*N*) and steering engine (*J*).
...	...	...	...	...	...	24	...	6.366	...	
4 -7½	8302	9262	9262	1630	1630	24	‡	5.942	...	Air pump would not work compound on account of low steam pressure. Steam was by-passed to L.P. cylinder, which, acting as a simple pump, did all the required work; exhaust connected to main condenser.
...	...	...	...	...	...	24	‡	6.048	...	
2 -7	8690	9128	18390	1571	3201	24	‡	6.791	...	
...	...	...	...	...	...	119	...	32.061	...	
...	...	9195	9195	1600.5	...	23.8	...	6.412	...	
6½-7½	...	...	...	...	...	23	‡	7.626	...	Weight of condensed exhaust steam, recorded in columns 25 and 26, is from the following auxiliary machinery: Feed pumps (*B*), dynamo (*H*), blower (*N*) and steering engine (*J*).
...	...	...	...	...	...	24	‡	7.215	...	Air pumps operating as in Test B. Water service and bilge pumps not in use during test.
5½-9	7615	7615	7615	1431	1431	24	‡	7.427	...	
...	...	...	...	...	...	71	...	22.268	...	
...	...	...	...	...	...	23·7	...	7.423	...	

Total steam used per hour by auxiliary machinery in operation.

	Test A.		Test B.		Test C.	
Steam used by air pump	7.365 × 83.18 =	612.6	6.412 × †100 =	641.1	7.423 × †100 =	742.3
Steam used by stoker motors	6 × 23.1 =	138.6	6 × 23.1 =	138.6	6 × 23.1 =	138.6
Steam used by other auxiliaries	=	1622		1600.5	=	1431
Total		**2373**		**2380**		**2312**

SUMMARY OF TESTS OF MACHINERY OF MINNESOTA

MAY 28–

Number of table.	Date.	Duration of test. Hours.	Average boiler pressure. Gage.	Main engines.						Feed					
				Steam pressure at engines. Gage.	Vacuum. Inches.	Cut-off in H.P. cylinder.	M.E.P. reduced to L.P. cylinder.	Revolutions.	I.H.P.	Average temperature leaving heater.	Total pounds.			Pounds	
											Fed to boilers.	Used by main engines.	*Used by auxiliaries.	Main engines.	
														Total.	Per I.H.P.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	1899.														
1	May 28.....	6	242	239.4	24.35	.644	31.48	77.33	1206.71	222	122439	103509	18930	17252	14.30
2	May 30.....	6	244.2	238.1	23.56	.658	31.70	74.45	1169.77	213.2	116136	100167	15969	16694	14.27
3	May 30–31.....	6	240.8	237.2	22.73	.798	36.93	79.44	1455.04	219	146089	125711	20378	20952	14.40
4	May 31.....	6	245.3	241.8	22.71	.542	26.24	66.31	862.78	226.5	89566	76351	13215	12725	14.75
5	June 1.....	6	245	241.8	23.67	.656	32.01	73.74	1168.88	181.5	98026	...	...	...	...
6a	June 1.....	3	197.4	193.4	23.40	.656	25.71	67.10	855.87	200.1	45937	38818	7119	12939	15.12
6b	June 1.....	2	129.8	125.8	21.60	.656	15.59	51.02	394.94	217	18390	13630	4760	6815	17.26
6c	June 1.....	1	108.3	104.3	21.16	.656	11.87	44.93	264.89	218	7615	5303	2312	5303	20.02

*Includes steam used by stoker engines.

STEAMSHIP COMPANY'S STEAMER *PENNSYLVANIA*.

JUNE 1, 1899.

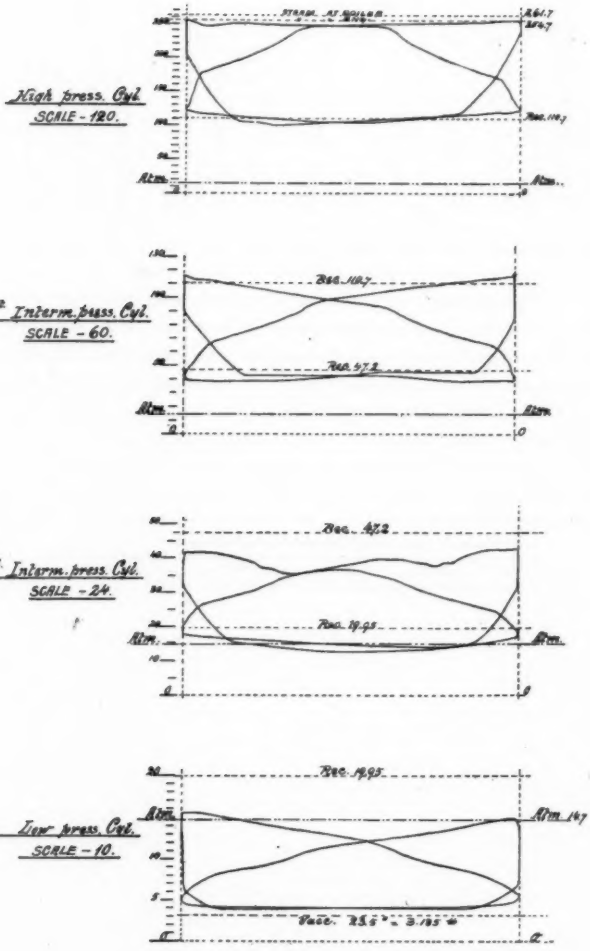
water.					Coal.						Refuse.		Water evaporated.				
per hour.							Dry coal. Pounds.						Per pound.				
Auxiliaries.								Per hour.					Dry coal.		Combust'le.		
Total	Per I.H.P. developed by main engines.	Total per I.H.P. developed by main engines.	Exhaust steam actually sent to feed heater in per cent. of total steam used for all purposes.	Per cent. of total steam used by auxiliary machinery in operation.	Total pounds.	Per cent. of moisture.	Total.	Total.	Per I.H.P. main engines.		Total.	Per cent. in dry coal.	Actual conditions.	From and at 212 degrees.	Actual conditions.	From and at 212 degrees.	Remarks.
									Main engines.	All machinery in use.							
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
3155	2.61	16.91	14.78	15.46	14400	3.3	13925	2321	1.63	1.92	2183	15.68	8.79	9.24	10.43	10.96	*a*.
2661.5	2.28	16.55	13.02	13.75	14200	3.3	13731	2289	1.69	1.96	2575	18.75	8.46	8.97	10.41	11.03	...
3396.3	2.33	16.73	13.08	13.95	18000	3.3	17406	2901	1.72	1.99	3800	21.83	8.39	8.85	10.74	11.32	*b*.
2202.5	2.55	17.30	13.83	14.75	11800	3.3	11411	1902	1.88	2.20	2463	21.58	7.85	8 21	10.01	10.47	*c*.
...	...	16.77	...	...	14750	3.3	14263	2377	...	2.03	...	...	8.25	9.02	...	...	*d*.
2373	2.77	17.89	10.59	15.50	...	...	...	...	...	...	...	...	...	...	...	...	...
2380	6 02	23.28	17.41	25.88	...	...	...	...	...	...	...	...	...	...	...	...	...
2312	8.73	28.75	18.79	30.36	...	...	...	...	...	...	...	...	...	...	...	...	...

a. Preliminary tests; weight of coal used unreliable.
b. Auxiliary water exhausted to atmosphere by blower equal 432.8 pounds.
c. Leak around gland of feed pump during test equal 396 pounds.
d. Total feed water weighed only during five hours of test.

S.S. Pennsylvania. Sheet 34. a

Card No. 7. – 5.00 P.M. – May 30. 1899. – Table II.

Average Power.

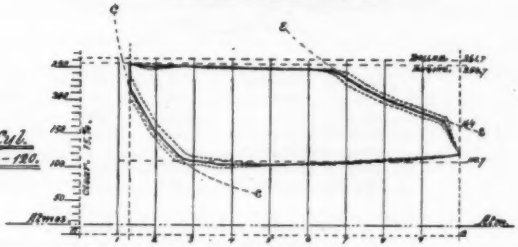


S.S. Pennsylvania. Sheet 34.b.

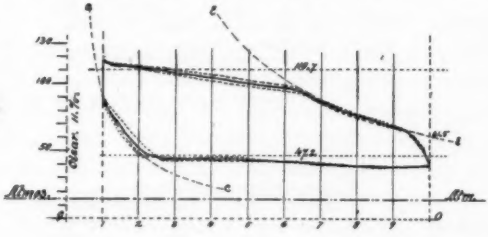
Card No. 7. – 5ᵒᶜ P.M. – May 30. 1899. – Table II.

Average Power.

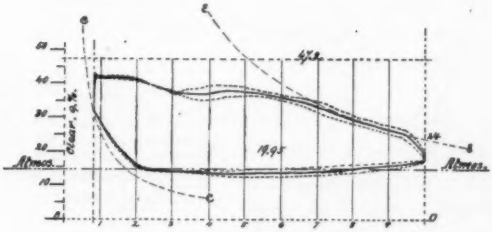
H. P. Cyl.
SCALE – 120.



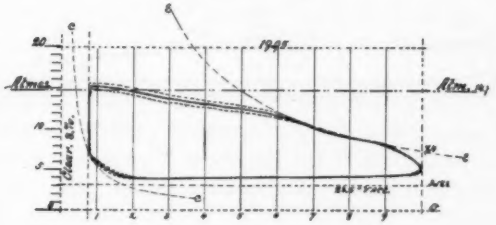
1st. I.P.Cyl.
SCALE – 60.

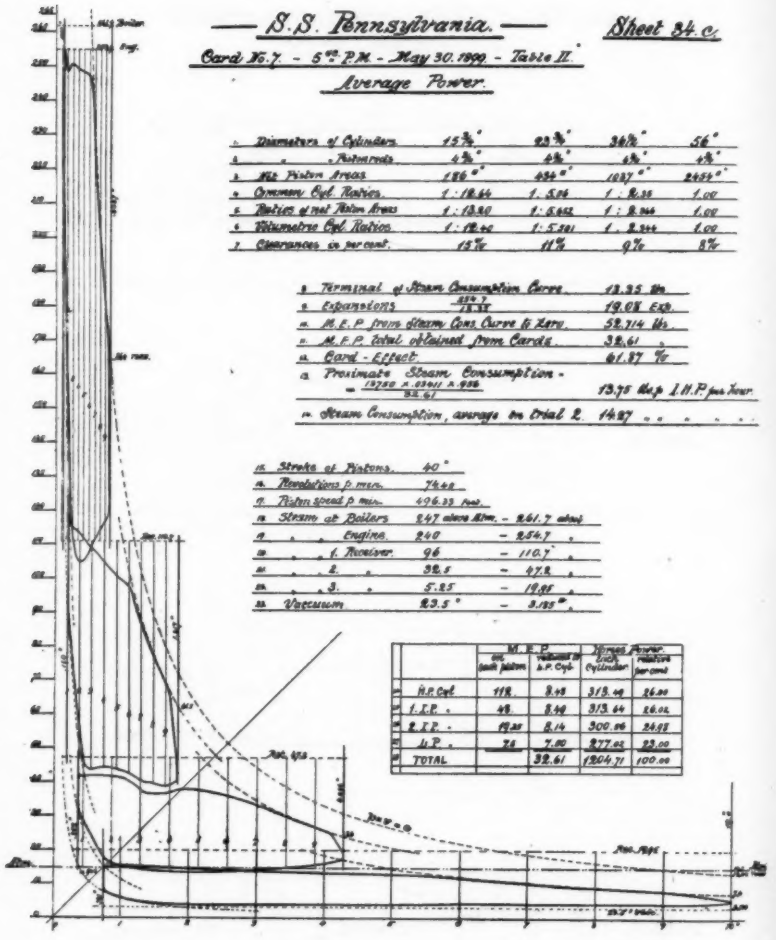


2d. I.P. Cyl.
SCALE – 24.



L.P. Cyl.
SCALE. – 10.





S.S. Pennsylvania.

Sheet 34.c.

Card No. 7 - 5th P.M. - May 30. 1899 - Table II.

Average Power.

a. Diameters of Cylinders	15¾"	23¾"	36½"	56"
b. " " Pistonrods	4¾"	4¾"	4¾"	4¾"
c. Nett Piston Areas	186"	434"	1027"	2455"
d. Common Cyl. Ratios	1 : 13.44	1 : 5.66	1 : 2.39	1.00
e. Ratios of nett Piston Areas	1 : 13.20	1 : 5.652	1 : 2.366	1.00
f. Volumetric Cyl. Ratios	1 : 12.96	1 : 5.581	1 : 2.344	1.00
g. Clearances in per cent.	13%	11%	9%	8%

h. Terminal of Steam Consumption Curve $\frac{854.7}{13.35}$	13.35 lbs.
i. Expansions	19.08 Exp.
k. M.E.P. from Steam Cons. Curve & Zero	52.714 lbs.
l. M.E.P. Total obtained from Cards	32.61 "
m. Card - Effect	61.87 %
n. Proximate Steam Consumption = $\frac{10750 \times .0301 \times 958}{32.61}$	13.75 lbs. I.H.P. per hour.
o. Steam Consumption, average on trial 2.	14.27 " " " " "

p. Stroke of Pistons.	40"		
q. Revolutions p. min.	74.42		
r. Piston speed p. min.	496.33 feet		
s. Steam at Boilers	247 above Atm.	=	261.7 abs.
t. " " Engine	240	=	254.7 "
u. " " I. Receiver	96	=	110.7 "
v. " " 2. "	32.5	=	47.2 "
w. " " 3. "	5.25	=	19.95 "
x. Vacuum	23.5"	=	3.125 "

	M. E. P. on each piston	Volumes of H.P. Cyls.	Horses Power. Each Cylinder	Horses Power. relative per cent
H.P. Cyl.	118.	2.48	313.04	26.00
I.P. "	48.	2.49	313.64	26.04
2.P. "	19.25	2.14	300.96	24.98
L.P. "	7.1	7.00	277.03	23.00
TOTAL		32.61	1204.71	100.00

CONCLUSION.

Engine.—From the results of these tests, it is apparent that the steam consumption of the quadruple-expansion engine of the *Pennsylvania* shows no economical gain over ordinary engines of the triple-expansion type as now designed for pressures approaching 250 pounds. Several assignable reasons may be advanced as accounting for this. It is probable, however, that the most cogent factor lies in the ratio between the first and final cylinders, which should have been larger for economical working at the horsepowers developed at the usual speed of the vessel.

Typical indicator cards from the main engine, and the combined card, are herewith appended.

Auxiliaries.—The prevalent custom on vessels engaged in traffic on the Great Lakes has been, until recently, to attach all necessary auxiliary machinery operated in connection with the main engine (air, feed, bilge and water-service pumps,) directly to it. Although not so convenient or satisfactory in many respects as compared with independent auxiliaries, this plan has unquestioned advantages in steam economy.

With the general introduction of water-tube boilers, however, and the consequent practical necessity for independent feed pumps, which, in turn, led to the installation of feed-water heaters, the loss in economy within limits due to independent auxiliaries has been largely overcome.

As before stated, all auxiliaries on the *Pennsylvania* are independent. Those run regularly when the main engine is in operation, viz: air, feed, bilge and water-service pumps, are of the compound type, and show fair economy in steam consumption per unit of power. The economy of other auxiliaries, except fire-room blower, dynamo and steering engines, is unimportant, since they are only periodically in operation and generally for small intervals of time.

Of the auxiliaries above mentioned, the dynamo engines—each of which consists of a single cylinder with piston valves—are apparently the most expensive in steam per I.H.P. developed. It is to be noted, too, that the tests show considerable difference in

the economy of the port and starboard engines when carrying about the same load. This, no doubt, is attributable to steam blowing directly into the exhaust from faulty fit of the port engine piston valve.

During the experiments the effect of increasing the temperature of the feed water to about 225 degrees, or above, in the heater, was noticed to be detrimental to the efficient action of the auxiliaries. At such times, on account of the excessive back pressure in the heater shell, much readjustment of the auxiliaries' throttles was required, causing "kicking" of the various pumps, and necessitating constant care. The upper limit of feed-water heating for thorough efficiency on the *Pennsylvania* seems to be about 200 degrees, amounting to an average rise in temperature of the water taken from the hot well of, approximately, 95 degrees. From the tests it is seen that this result is accomplished with the auxiliaries consuming about 10.5 per cent. of the total steam generated by the boilers. The cost, therefore, of operating independent auxiliaries in connection with an exhaust feed-water heater, as compared to attaching them to the main engine, when the above percentage is not exceeded, is only trifling, and more than offset by the many obvious advantages of independent machines.

A STUDY OF THE ENERGY OF THE BOW WAVE.

By Marston Niles.

"It would seem that a certain pride in mathematics has prevented those engaged in these investigations from availing themselves of methods which might reflect on the infallibility of reason. * * * As regards the direct object in view, the revelation of the actual motion of fluids, the research has completely failed. And now that generations of mathematicians have passed away * * * the simplest problems of fluid motion are yet unsolved."—Professor Osborne Reynolds, *Proc. Royal Inst.*, February 2, 1877.

When a ship is in rapid motion certain forms and forces are developed in the surrounding water. The prevailing opinions respecting these are based upon the labors and conclusions of a long line of distinguished mathematicians and experimenters, and are in substantial harmony with each other.

It is my desire to set forth sundry reasons for believing these opinions, together with their mathematical bases, to be in almost every respect erroneous, and for believing the conclusions which have been drawn from certain experiments to have been deduced in an improvident manner.

Wave resistance may not improperly be conceived as a fringe, seam, or peculiar selvedge along the side of the fabric of stream resistance. Before the warp and woof of this fabric can fairly be unraveled it is necessary to detach the selvedge. Therefore we must first dispose of the matter of wave resistance.

The following picture is a reproduction of one given by William Froude. I have added letters and figures to the picture.

The height of the waves in this figure was made twice their height in the experiment which the figure is supposed to represent. This he did for the sake of distinctness.

The water rises into waves because it is struck by the advancing bows, or by other water which, having been struck by the bows, has taken upon itself somewhat of their contour. On

being thus struck, it is displaced. In an ahead-and-sideways direction it cannot entirely be displaced, because other water ahead-and-sideways does not readily give place to it. Therefore relief is found in a plane above the level, where there is room abundant. Thither it rises, albeit unwillingly and against its gravity. Having now been hove up above the position of equilibrium, it next, at once, proceeds to sink as far, or nearly as far, below that situs. In this rising and sinking, and in continuing to vary from the plane of equilibrium, it begets two sets of water agitations, both of which have been called waves, although only one set consists of waves in fact.

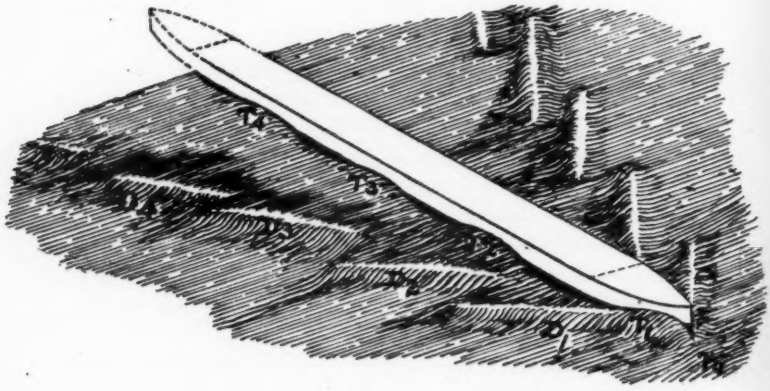


Fig. 1.

The foregoing figure is worthy of the closest study. In it may be roughly perceived, as far as the ship's forebody is concerned, the sum and substance of the principles of wave resistance, or, in other words, the causes of that waste of horse-power which consists in the useless hoisting of a weight of more than a quarter of a ton to the cubic yard, a waste which at high speeds becomes enormous. At her stern, a ship begets two other sets of waves resembling the forward systems, in producing which a clash between water and water replaces the clash between bow

and water which took place forward. This makes an additional waste of horse-power at the stern strictly proportional to the cubical mass of the waves made there. Neither of the two sets of stern waves is represented in the figure.

The type of ship here pictured is a rather old-fashioned one, with a long, parallel-sided middle body. This type was chosen, not for the excellence, but for the badness of its form, and for its exhibiting the most malignant developments of wave-making tendencies. I have marked each wave on the starboard side with a number. The skew-shaped or scantling ones are the so-called "diagonal" waves. They are marked D^1, D^2, etc., etc. The masses whose outlines are seen in wavering form upon the ship's side are the thwartship or so-called "transverse" waves. They are marked T^1, T^2, etc., etc.

In the following discussion, for the sake of convenience, the term "bow wave" will be used to signify merely the transverse element of that wave, and will exclude the diverging wave, unless the contrary is directly indicated.

THE TRANSVERSE BOW WAVE.

All the authorities with which I am acquainted hold, variously, that the whole or a part of the energy which throws up the bow wave is gotten from the waves which are behind it. Those of them who have treated the subject in the fullest manner, trace an even half of this energy to the waves behind.

The question is far from being merely one of theory. If the authorities are in error, a radical departure from the prevailing water lines is called for. I shall endeavor to show that the accepted theory is contrary to the fact, and that the subsequent members contribute no energy whatever to its formation. The whole energy is traceable to the reaction between the ship's bows and a certain crowded mass of water, and is furnished by the ship alone, and by the ship immediately.

Professor Rankine holds that the principal loss of power at the bow takes place through the diagonal wave, and that the transverse train, once started, is not a cause of sensibly increased resistance. He bases this conclusion upon the circumstance that

long waves, such as are raised by ships, are capable of traveling great distances without sensible loss of energy. It is clear that he looks upon the transverse train as traveling with the ship, as retaining at the bow nearly all the energy which it possessed further aft, and as delivering up the whole of it to the bow wave, the leader of the system; and he considers that into the bow wave is received, for and toward the propagation of the system, all the system's energy, save such as goes abroad in the mass of the divergent wave, and save, of course, what may be lost in friction. ("Shipbuilding," pp. 79, 80.)

Professor Lamb lays down a principle identical with Rankine's, except that he treats only of the case where the train consists of a bow member and a stern member without any waves between. "A free surface" of the fluid, says he, "at a great distance from it also has little effect on a solid. The case is otherwise, however, when the solid is only partially submerged, *e. g.*, a ship. One effect of the motion is to make the pressure deviate from its statical value; to increase it, for instance, at the bows and at the stern, and to diminish it amidships. Hence the level of the fluid is disturbed, and there is *an elevation of the water at each of the former points, and a depression between.* A wave like this accompanying the ship would, of course, *cause no loss of energy* beyond what is necessary to maintain it against viscosity.* But we have also waves produced which travel over the surface, and carry off energy to distant points of the fluid. The energy thus dispersed must, of course, come directly or indirectly from the ship; and the loss from this cause contributes a special form of resistance called 'wave resistance.'" (Motion of Fluids, p. 247.)

Nearly identical with the doctrines of Professors Rankine and Lamb is the view of the great constructor Sir William White, who says, "When such a ship has reached her uniform speed, and the waves have been *fully formed*, the *maintenance* of these waves will require a certain expenditure of force which measures the wave-making resistance. The case is parallel to that of the

* "This is easily seen by impressing on everything a velocity equal and opposite to that of the ship, and so reducing the case to one of steady motion."

deep-sea waves (described at p. 217), which travel over immense distances without any great loss of speed, but with this important difference, that, whereas the ocean waves *gradually become degraded*, the waves accompanying ships, under the favorable circumstances described, *are kept to their full height*." (Nav. Arch., p. 455.)

In his admirable paper on "*Leading Phenomena*," etc., the doctrine of Mr. R. E. Froude is, that half the energy of the bow wave comes from the train abaft it, and that half is contributed by the ship. He bases this doctrine on the facts that "a system of deep-water waves does not travel as fast as the individual waves composing it," and that "the energy represented by the wave motions is transmitted from particle to particle in the direction of the travel of the wave by the mechanical conditions of wave motion; but this transmission is only effected at half the speed of the individual waves." "We now see, then," says he, "that the work a ship has to do in maintaining a wave system, whether of transverse or diverging waves, is, in fact, equivalent to adding to the system one new wave for every two wave lengths she travels." (Leading Phenomena, etc., Trans. Inst. Nav. Arch., 1881.)

In the *Proc. Inst. Civ. Eng.*, Vol. XXXII, p. 243, we find William Froude declaring that "it is now well known that if the divergent waves generated by the ship *in transitu* were excluded (which with a well-formed ship moved at a moderate speed were trivial), these frictionally-created movements were responsible for the entire resistance which the ship experienced." That is to say, he fully accepted Rankine's theory that when the transverse train has been once established, no energy, or no considerable energy, is expended in its maintenance, except what is necessary to supply the loss occasioned by the divergent waves. It is not strange that William Froude accepted Rankine's inference. He was, perhaps, disposed to look on Rankine's theories in general as he looked upon the law of gravitation; this is why we find him taking as quite for granted the reliability of Rankine's theory as to the resistance of the bow wave. This magnificent

man had work on his hands more important than even the laying out of theories. His bent of mind was toward positive ascertainment rather than toward the drawing of inferences. Apparently it was his custom to lay light stress upon divining what the fact *ought to be*, and to lay great stress upon finding out what the fact *is*. Principles were to be evolved from stuffs and shapes in the external world, through, and not out of, changes of form in the substances of the brain. Perhaps he believed he had no business to think in respect to a matter in which he could make it his business to behold. Theories were well; but the theory adopted by the things themselves under consideration, as a rule for their conduct in a given situation, was the best theory for the student of phenomena to adopt, and the student was to find out, by experiment and not otherwise, this theory. Froude willingly bowed to Rankine's hypothesis, until the facts should present him with another.

Professor Durand agrees substantially with Mr. R. E. Froude, in that he says that "the group as a whole may be considered as the expression of a certain distribution of energy, and hence the velocity of the group may be considered as the velocity with which the energy is propagated, as distinguished from the velocity of the individual waves. It must be considered, therefore, that in waves of trochoidal character the energy is propagated at only one half the velocity of the waves themselves. * * * It seems allowable to assume for the waves of this system such further properties of trochoidal waves as may be convenient for their investigation. * * * It follows that for every two wave lengths run the ship must supply the energy necessary to the formation of one wave. Let us assume that one-half the energy is naturally propagated with the form, and that one-half must be made up by the ship." (Resistance and Propulsion of Ships, pp. 89, 94, 96.) But Professor Durand is careful to observe that "the exact fraction of energy which falls astern relatively to the ship will depend on the geometrical character of the wave; and it must not be considered that the ratio $\frac{1}{2}$ is anything more than an approximation, which, however, may serve for illustrative pur-

poses" (p. 95). Therefore, the agreement of Professor Durand with the other commentators appears to amount only to this, viz: that the bow wave is produced in part by the ship and in part by the train abaft it.

Mr. D. W. Taylor enters into this subject with his customary exhaustiveness. He supposes the transverse system to consist of trochoidal waves marching steadily with speed equal to that of the ship. "Advancing into still water," *i. e.*, into the motionless fluid just ahead of the bow, "such a system carries its potential energy with it; but the kinetic energy of the new particles, constantly set in motion, must be derived from work done by the wave resistance of the ship." He makes the kinetic energy of the mass, due to the rotation of its particles, to be precisely equal to the potential energy of the mass, due to its mean center of gravity being raised above the position it would occupy if the water were at rest. Letting w equal the weight per cubic foot of the water, and l the length of the wave, and b its breadth, and H its height from crest to hollow, he makes the kinetic energy, which must be furnished afresh by the ship, to be equal to $\frac{1}{16}\ w b l H^2$; and this same $\frac{1}{16}\ w b l H^2$ he makes equal the potential energy which the transverse system transmits to the bow wave and contributes to its formation. (Resistance of Ships, etc., pp. 43–45.) Thus in his dividing equally the burden between the ship and the train, he is entirely at one with Mr. R. E. Froude and with Professor Durand. But he furnishes a fullness of formula in which Mr. R. E. Froude is lacking. Upon this subject Mr. Taylor may be regarded as bringing up to date the matured and clarified doctrine of the mathematicians.

The claim, then, of the authorities is, variously, that (*a*) the whole, (*b*) the half, (*c*) some part, of the energy that throws up the transverse bow wave is put into it by the waves behind it. That is to say, that in Fig. 1 (page 592), the force or work necessary to bring level water like the water marked T^0 to the height and character of the form marked T^1 (understanding by T^1 so much of the wave as does not belong to D^1) is wholly, or in half, or in some part, contributed by the waves T^2, T^3, T^4, aided per-

haps by other waves which are supposed to be coming up still further astern and which are not exhibited in the picture.

The seaman can hardly admit this claim.

To affirm that at a given instant the ship is furnishing but half the energy which creates the wave T^1, and that the troop T^2, T^3, etc., are furnishing the other half, is to affirm that at each and every instant, or during a whole unbroken voyage—as, for example, from New York to Liverpool—the ship furnishes but half the energy, and the troop itself the other half. For, excepting at the time of gaining headway at the beginning of the voyage and losing it at the end, the instants are all alike and the waves all alike. The whole track of the ship from one port to the other is made up of waves exactly like the above-pictured bow wave and its troopers.

If the mathematicians should admit that the ship has primarily energized the troop, but allege that nevertheless she has constituted the troop a depository of energy to be by it surrendered from time to time for application upon the bow wave, the seaman will wish to know by what track or channel the troop receives the energy, and by what track or channel it is handed back. For it must appear to him that whatever energization the troop has received has been conveyed to them by and through the bow wave itself; or, more strictly speaking, by and through bow waves of elder birth indeed, but each one of them exactly like the current or now-existing bow wave.

This indeed will hardly be denied. But if the energy required for casting up the current bow wave has been furnished wholly or in part by the following troop, the troop having been energized for that purpose by previous bow waves, we may lawfully strike out the troop as being a mere *conduit* of energy, and in contemplation we may short-circuit this contributed energy by passing it directly from an earlier bow wave, or from several earlier bow waves, to the current bow wave. Short-circuit or long-circuit, this theory makes an earlier bow wave a purveyor of energy for a later bow wave, and it throws upon the earlier bow waves a burden of undue gravity, and it unduly lightens the burden of the current bow wave. In an extended voyage a

fearful charge would be resting upon the earlier bow waves, and thereby upon the engines during the earlier part of the voyage. It is upon the engines that the demand really tells; for the ship's hoard of energy or impetus lasts for a few moments only, and must be constantly replenished by the engines.

In any case, it would be intolerable that a stream of energy should have been pouring aft from the earlier bow waves into the troop in order to energize through them the current bow wave; for the current bow wave is in turn bound to hand aft to the troop a stream of energy for the behoof of future bow waves; hence whilst it is engaged in receiving *from* aft its incoming stream of energy it would be at the same time engaged in delivering *toward* aft an out-going stream, and these two streams could not but clash and they both would be destroyed.

How complicated and how contradictory is this theory! How simple, on the other hand, are the facts! The ship's engines, through fresh momentary thrust, assisted by previous thrusts which lie hoarded away in the ship's impetus or *vis viva*, deliver each instant to the bow water the quantum necessary for the push and hoist of that instant. This hoist and push instantly make the water into the bow wave of that instant. The water of the bow wave, on falling from the height which it attains, bounds and rebounds upon the water-bed during succeeding instants, the ship's side meanwhile passing it gradually by; thus the adjacent water is rumpled into the semblance of a troop of waves, and, indeed, of a troop which appears (but only appears) as if it were moving forward and dogging the heels of the bow wave. In point of fact, all energy passes from the original bow wave to the troop behind it. This troop consists merely of echoes or reboundings on the part of the masses of water which earlier have occupied the bow wave position, and whilst in that position have acted the part of leading or bow wave. It is clearly impossible that any energy whatever should pass from the troop to the bow wave. The bow wave truly is the cause of the troop; *i. e.*, previous bow waves have caused the troop. The troop are constitutionally in dependence upon the bow wave for original existence as well as present subsistence.

FROM WHERE DOES THE ENERGY COME TO THE TROOP?

If energy is to pass from the waves that follow, into the wave that leads, this energy must first be gotten into the waves that follow.

From whence is that energy derived? From the afterbody? No. The afterbody in many cases makes, visibly or invisibly, a hollow of water, a sagging of water below the level along the counter. Now a hollow shows, not energy, but a defect of energy. Even if this last be not agreed to, it will be agreed that whatever demand is made by the hollow is satisfied by the rise or wave astern of the hollow—a wave rendered possible by the hollow. The up-flowing and convergent clashing streams whose tardiness of motion has caused the hollow, now, on the contrary, fashion themselves into the stern wave. They rush upward and rush inboard, and on the front of that wave build it up, prolonging it exactly one inch for every inch that the ship advances. As the stern of the ship advances, the under streams rise from beneath her and the side streams clash abaft her, and they all rise into a heap which is constantly added to at the front of the heap, and just as fast as the stern moves forward. This statement contains pretty nearly the whole doctrine of the stern wave. Each mass of stern wave is begotten from water just forward of itself, and its energy passes to posthumous offspring following at the heels of the next succeeding mass of stern wave. None of that energy can spring from the stern wave toward the fore and go forward to the bow.

Nor does the energy of the waves that follow the bow wave come from the waist. There is nothing in the waist that can throw up a wave. Or if, as in the torpedo boat at high speed, the waist aids in throwing up the wave, then the waist is, so far, a continuation of the bow, and the waist's function is a continuation of the function of the bow.

Still idler would be the supposition that the screw gives the transverse system of waves its energy. The push of the screw upon the water is sternward, and it is reckonable in terms of slip. In another way, indeed, the screw's motion does impart the energy, viz: through the bows, for it drives the bows against

the water; but it does not avail to cast up the troop, except by casting up the bow wave which itself casts up the troop.

The origin of the bow wave is simply this.—Some portion of certain water which, before the bows reached it, lay stretched abroad for perhaps a ship's breadth between certain outboard water and a line projected due forward from the cut-water, becomes, when the expanding bow-contour reaches it, crowded for quarters. Instantly it is compelled to give up to this advancing contour some of its in-and-outboard or y dimension, and also some of its fore-and-aft or x dimension, and consequently is compelled, by the incompressibility of water, to take up an increased vertical or z dimension. This mere increase of vertical or z dimension is what we call the bow wave.

Since the bow wave consists of the raising higher of a substance that has gravity, it obtains thereby a potential energy due to gravity and to elevation. As soon as its particles, moving aftward, pass in succession a certain critical point on the side of the bow, they fall in succession with an energy that is actual.

On falling, they displace other water; the water thus displaced is raised, and in rising acquires a potential energy. When this last subsides, it subsides with an actual energy, and, in subsiding, raises the original wave water (which meanwhile has relatively moved aft) to a point of potential power again.

These alternations of energy, actual and potential, between masses of water, constitute the whole of the energy of the transverse train. This whole energy comes from the reaction between the bow and the water there, the energy of the reaction being converted immediately into potential energy in the bow wave to an amount proportioned to its mass and elevation.

To go into detail.—The as-yet-humble water just ahead of the bow obtains the wave elevation by virtue of (*a*) the push of the screw blades against the reacting water behind the blades; (*b*) the rigidity or uncrushableness of the ship between the thrust block and the spreading contour of the bow; (*c*) the unyieldingness of the bow structure to the water which rushes against it; (*d*) the reaction of certain well-outboard water against the

outboard pressure of crowded water lying between it and the advancing bow—a reaction partly owing to its inertia and partly to viscosity, which viscosity has hitherto caused both itself and the intermediate or crowded water to refrain from earlier swerving duly sideways in obedience to pressure from the bow during the time while the bow was still distant; for, had there been due previous swerving, there would have been no congestion and, therefore, no wave; and, finally, (*e*) the inertia of the water bed, consisting of the lower strata which are unable so quickly as in a single instant to sink beneath the weight of the hill of water that overlies them, or to distribute in widely radiating directions its pressure and their mass.

HOW LONG WOULD THE TROOP'S STORE OF ENERGY LAST?

Let us view the matter from a somewhat different standpoint. Assuming for a moment that there is energy which now is pushing from the following train of waves towards and into the leading or bow wave, it still is true that there has been a time when the ship having but just reached full headway and but just finished the starting of the train, the output of energy pushed (as the commentators contend) into the bow wave, was the first full and perfect installment of energy. Let us now place ourselves there at the instant at which that first installment of energy was duly handed forward, and at which it empowered, or at least assisted, the bow wave to continue its career. The first installment having now been furnished forth by them to the bow wave, from where are the would-be helpful waves abaft it to get energy out of which to hand forward to the bow wave the next installment, lacking which the bow wave would, according to the commentators, surely dwindle? From where shall those following waves get the third, the fourth, the thousandth, the millionth installment which they must hand over? For these will all be called for in a long, unbroken voyage. A certain store of energy, indeed, the train may at the outset have acquired from some quarter quite unnoticed during the wave confusion which prevails while acquiring headway. But this outfit of energy cannot last forever, nor miraculously be handed forth in perpetuity, like eggs from

the sleeves of a conjuror. From somewhere must come the supply which the train is to be constantly delivering over to the fore. I ask, is there any possible source for it but the bow wave itself? If not, will the commentators seriously contend that the troop gets energy from one bow wave, and then hands it over to the next bow wave? Remember there is really no division of the bow wave into parts. It is simply one continuous rise of water from New York to Liverpool. The eye is merely playing the same old trick upon the brain.

THE ENERGY IS BRED WHERE THE RESISTANCE IS.

Let us view the matter in a more fundamental manner. It is forward that the ship is moving, according to the wont of ships. It is when she is in forward motion that these waves are begotten. They are quite unknown with ships at rest. To all forward motion there is wave resistance. If the water should indeed be running forward at the ship's own swinging gait, as when the ship drifts bows-on in a current, there would be no wave resistance, and therefore no bow wave. Clearly the bow wave is the offspring of wave resistance. Now the bow is that part of her that encounters wave resistance, and indeed manufactures that resistance, and at that very spot, viz: the bow; and there at the bow in fact we behold the bow in the act of producing the bow wave. It is the business of the bow and of its resistance to make that wave, and truly they are equal to their business. We should be carrying coals to Newcastle if we brought supplies of energy from abaft or elsewhere to assist the operation of piling up bow water into a bow wave. If from abaft we brought up some additional supplies of energy and put them at the labor, we should shortly roll up a wave which would overrun the forecastle and which no engines could overpower.

THE ONLY WAY TO TRANSPORT FORWARD A TROOPER'S ENERGY.

But if still we are determined to bring this energy forward, we cannot at any rate bring it through the water. There is no means present for transporting it through the water, for none of these transverse waves have the circular motion which the ocean waves

have, and by which alone the ocean waves are enabled to trundle onward their energy as a girl does her hoop.*

The transverse waves which follow are mere subsequent bouncings, ballotings, reverberations, rëechoes, of the leading wave. They are mere effects of the leading wave. They cannot face about and pretend to be its cause. There is only one way in which an echo of the bow wave can send its energy forward. It is by our choosing for the performing of its reverberation a spot in which its particles, in rebounding upward under the stress of gravity of other particles, will press against the up-and-aft-and-outboard-sloping under surface of the afterbody near the stern; a spot in which, but for the up-swelling motion of these particles, there would now be a hollow and a defect of pressure near the stern. If we can contrive it that just here shall be where they rise upward, they now will help to urge the vessel forward, and, as a later-rising generation, they will accomplish, if I may say so, a genuine if tardy restitution for the evil formerly committed by their lineal ancestor at the bow. It is this echo work of which Mr. R. E. Froude treats in his admirable paper of April, 1881; yet I cannot but think he would have made the matter far clearer had he first brought to view, with proper apparatus, the actual up-motion of the particles of the echo, and had he then pictorially or graphically resolved the energy of that motion into its vertical, its in-and-outboard, and its beneficial fore-and-aft components—in other words, had he resolved into its component x, y and z elements the line normal to the under afterbody surfaces which represents the resultant total onset and effective pressure of the rising particles of the stern wave made to form at the proper spot.

IT IS IMPOSSIBLE TO CARRY OUT THE THEORY.

When Mr. R. E. Froude observes that the work which a ship has to perform in respect of the transverse train is only "that of continually *lengthening* the system at half her own speed," *be-*

*This subject is too complicated to be dealt with in the present paper. For present purposes it may be sufficient to beg the reader to observe that the waves of the transverse system have not, as those of the ocean system have, the forward lunge along the crown, and the backward surge along the trough, which distinguish all rotary waves. Notice a boat, or even a chip, floating in the transverse system.

cause "the speed of the system is exactly half that of the waves," it is impossible for seamen to follow the thought-process by which he advances.

If I am traveling by express and cannot produce my ticket, and have by me in cash only half the fare, it will not avail me that my son is traveling by accommodation train a little later and carries as much more cash in his pocket book.

If my horse must beat 2·12 in order to win a race, it cannot help me that I have also in the same start a promising colt of his that can be counted upon for a speed of four minutes and twenty-four seconds.

If I hope to get ten knots out of my steam launch, I shall not borrow my neighbor's, which is good for five knots only, and let that puff and toil in tow behind me to help on. If, for appearance's sake, I must not cast her off, I shall beg that she disconnect, or better, hoist her screw, and by all means do the least she can in assistance.

In like manner, if the bow wave has to drag, at a certain speed, a lot of hangers-on which are unable to go of themselves at more than half that speed, the bow wave is getting no help, and it will do better to cut adrift from them and proceed quite alone.

Besides which, to double the speed of a wave takes more than double the energy. In order for a wave to move twice as fast as another it must be four times as long. If four times as long, it will be four times as broad, and four times as deep. To lengthen the system by doubling the speed, as Mr. Froude proposes, would require thirty-two times the power, in lieu of twice the power. If the reader is unable to agree to an increase of thirty-two times, he nevertheless will probably agree to a far greater increase than merely twice.

DO NOT CRY OVER SPILT MILK.

I think the point of view from which it has been customary to regard the subject of ship waves is one which predisposes us to see every portion of it in a wholly false light.' Mr. R. E. Froude says: "The question is not, however, What expenditure of energy must have been required to create the wave system, but

What rate of consumption of energy is involved in its maintenance when created." I think seamen, on the contrary, will say, Let us be very particular and deal with each wave quite distinctly, and not with systems and their maintenance. I think they will say, When once the energy has been expended in creating a wave it is a dead loss to us, and we do not care what becomes of the wave or its progeny, unless there is one of them that we can put in harness near the stern. If the wave has actually been raised, this means that the mermaid has already sneaked away with all the horsepower that she can steal. What the echo water does with itself afterward is of absolutely no moment. That it is of absolutely no moment may well appear from the fact that its moment is merely up and down, thus self-destroying, as far as its ultimate effect is concerned. All the agitations that are subsequent to the original mischief are only as the thunder to the lightning, or as the report of an occurrence is to the event itself. If engine power has been diverted for the hoisting of water, it is useless for us to watch the train of waves thereby created, or to speculate how long a dance they have vigor to maintain—excepting always, of course, that if we can catch one of the rascals near the stern, we shall get out of him, for our use, all the strength that remains in his legs. The seaman will fix his whole attention upon the *leaders* in the transverse systems, whether the bow system or the stern system. It is a waste of time and, worse, a wasting of useful powers of observation, to pay any regard to "the maintenance of a system," unless for the purpose just stated. Yet Mr. Froude's words are susceptible of a reasonable interpretation also.

THE OCEAN WAVE.

With the ocean wave, it is very true, the water on the front face of the wave is rising, and its rise does, in a certain sense, help in the raising of water which at present is in front of the wave. If this is the case with the ocean wave, why, it may be asked, is it not the case with the second member of the transverse system, and why does not the energy present in that member aid in the casting up of the transverse bow wave just ahead?

Without entering into the differences of the two systems with regard to internal structure, we may note with the eye a sufficient difference between them for constituting a reason why this should not be the case. In front of the ocean wave we observe a hollow. This hollow is, for wave-making purposes, just as useful as if it were a height from which the water could fall, for it represents, in its own depression, an elevation of other particles—an elevation due to that depression. The elevation of those other particles gives them an energy in falling which helps the water to rise on the front face of the wave, just behind the depression. The hollow in front of an ocean wave, then, is indidirectly a source of energy for the wave, just as much as the height which is attained by its particles is directly a source of energy for a repetition of the wave. For an overshot wheel we can get a fall just as well by digging out the bed below as by throwing up a dam above.

Observing the water in front of the bow wave, however, we find no such depression there, and, consequently, no such source of energy. Between this leading wave and the wave next abaft it, we do, indeed, find such a depression; it is a depression owing to the energy with which the water which has just been hoisted along the front of the transverse bow wave, has fallen from the height to which it was hoisted—falling perpendicularly thence, although the marching forward of the point at which successive particles begin to fall has the effect of producing an outline of falling particles which slants diagonally downward and sternward, and thereby causes an appearance as if the falling water were gushing sternward as well as downward. The depression, then, between the first and second members of the transverse system is, with respect to the first member, in the nature of mere effect, and is not in the least a cause. To the second member only does it stand in the relation of cause—of cause to a certain extent; for although the second member has a certain vigor of its own, being the rebound of particles which an instant earlier had fallen from the positions successively attained at the crown of the *then* first member of the system, still, this second member would be an enfeebled echo of the previous bow wave, were it

not reinforced by the energy implied in the depression between itself and the new bow wave. The energy, therefore, involved in the hollow does not transfer itself forward, or aid in lifting the front half of the bow wave. The weight of this wave must be lifted by a dead lift, it having in front of it no hollow to serve as a source of energy; and the lift must be furnished wholly by the present push of the screw and by the past pushes of the screw, whose energy lies hoarded in the impetus or *vis viva* of the ship's motion. In Fig. 1, observe that forward of T^1 there is no depression, but there is a depression between T^1 and T^2.

THE PREVAILING THEORY CREATES ENERGY OUT OF NOTHING.

Still another instructive side-view of the established theory may be taken as follows.—Neither a difference in model nor a difference in speed can change the essential character of the transverse system; but with all vessels and at all rates of speed this character remains the same. This being the case, it may advantage us to consider certain facts brought out by William Froude in experiments on "Parallel Middle Body" (Trans. Inst. Nav. Arch., March, 1877), and to consider whether these facts are consonant with the theory that a considerable portion of the energy of the transverse system passes forward into the leading or bow wave.

It was shown that a certain vessel 170 feet long, when towed at 14.43 knots, experienced a "residuary resistance" which, skin-frictional resistance having been subtracted, amounted to only about $7\frac{1}{4}$ tons. This was because the first echo of the bow wave, abaft, was produced in the most favorable location for pressing the afterbody forward. The same vessel, however, when lengthened to 220 feet by insertion of parallel middle body, and towed at the same speed, experienced a "residuary resistance" which amounted to about $16\frac{1}{4}$ tons, or more than double the former resistance. It was shown that this doubling of resistance was owing to the circumstance that the echo was then produced in the least favorable location for pressing upon the afterbody.

It is true that data which for my present purposes are most important, are lacking in his report; therefore it is impossible

to draw a perfectly reliable deduction. There is matter here, however, which calls for reflection.

The echo suffered undoubtedly a great loss of energy from friction and external diffusion as it passed aft. Moreover, its energy was not able to be applied to the afterbody with perfect effectiveness, as in the case of normal-surfaced water pressing with the insistence due to its own gravity and the gravity of neighboring outboard water which is backing up that pressure; since even during the application of its pressure the echo was falling away outboard and diffusing itself abroad. Nevertheless, the difference in total resistance produced by varying the point of its application, as shown by the foregoing figures, is most astounding. This reveals a vast amount of energy still remaining, for beneficial or for injurious application, in the echo, even after suffering the great losses to which I have referred—an amount which is quite inconsistent with the theory that at the outset it parted with half its energy to the bow wave. On the basis of that theory, indeed, by towing a line of vessels at such distance apart that the energy of the stern wave of a leading vessel would be suitably applied at the bow of a following vessel, and by thus economizing the energy of the stern wave as well, we should have the absurdity of being able to do away with probably all wave resistance, and perhaps even obtain a bonus of energy; and this in addition to creating, without expense, a vast frictional disturbance in the water by means of the lost energy of the echoes.

AN ECHO IS NOT NECESSARILY A WAVE.

A *current* is a transfer of substance and of energy. A *wave* is never, unless incidentally, a transfer of substance.

Some kinds of waves are transfers of energy, and some kinds are not. In the ordinary waves which are transfers of energy the particles usually take a circular or quasi-circular path, doing this in a vertical plane which extends in the direction of the transfer.

In waves which do not transfer energy the path is up and

down in alternation. They cannot properly be called waves, except in obedience to established usage.

Where energy is transferred by a wave, the transfer is accompanied by the forward movement of an undulating outline. This marching outline makes a march of Form but not of Substance. Along the forward face of the wave the particles are rising. Along its rear face they are falling. At the crown they are moving onward. In the trough they are sweeping to the rear. When we watch a wave coming toward us, we shall see two things: one, that the particles are climbing; the other, that the form or display of surface is coming forward. After the wave has passed us, if we turn to watch it we shall see two things: one, that the particles are sinking; the other, that the form or display of surface is retreating from us.

Thus the wave may, on its front face, be regarded as clambering or climbing forward, and, on its rear face, as sinking or *tumbling* forward. If we say that, in its trough, it sweeps *backward*, we must add that this is only in order to surge forward again along the crown of the succeeding wave. Flitting onward, the ocean billow carries no substance with it. Instead of the substantial, it wafts an empty form or outline. But with the form there flits the inscrutable thing called Energy, which rides the Form like a phantom knight on a phantom horse, crying Forward! at every bound.

Among the energy-carrying kinds of waves belongs the scantling wave, marked D, of Fig. 1, four examples of which are shown on the starboard side of the vessel and five on the port. But the scantling wave, though energy-carrying, like the ocean waves, is not, like them, gregarious. No scantling wave marches in company with others, or keeps in touch with any. It paces by itself, without leader and and without follower, a solitary straggler, soon to sink in its tracks exhausted. D^4 is an undulation which got its start a few moments earlier, at a time when the bow was near to where the stern is now. The bow threw it off sideways and facing a little forward, and since that time its form and energy have been carried, as may be seen, to a considerable distance outboard and to a little distance ahead. These several and independ-

ent undulations have none of them any concern whatever with the train of thwartship waves marked T. They enlisted for other reasons than those did, and they have deserted from the ship at the earliest instant.

The thwartship waves, on the contrary, are not of the energy-carrying kind. It is only in deference to usage that we can call them waves. It is only in respect to outline that their form is wavelike. Their form is wavelike in as far as it is an outline in which certain particles of the outline are seen high up and others are seen low down, and the rest are seen between high and low. The high parts of the outline sink and become the low parts, and the low parts rise and become the high parts. And they do this turn and turn about. But a wavering outline does not necessarily consist of particles which have acquired a forth-and-back as well as an up-and-down motion. A wavering outline is no test at all of wave-hood, and in the present case that outline is owing merely to the previous handling which the water particles have met with at the bow, and to the present handling which gravity gives them.

In Fig. 2, page 613, the particle which is at the point A^1 is at the very surface of the water, and will remain at the surface and next the ship's side till it leaves her at the stern, unless at the very outset it is entrapped in the scantling wave and perhaps gets rolled over. We may put a floating bottle, or a cork perhaps, at A^1, and thus mark for our purposes this special particle, since the cork or bottle will stick faithfully to the particle. By and by the cork and particle will be at the vessel's stern. This does not mean at all that they will have gone aft. It means exactly that the vessel's stern will have come forward and got to where the cork and particle are. The cork and particle will neither have come aft nor gone ahead meanwhile. They will only have been moving up and down. The waving line A^1, B^1, A^2, B^2, etc., etc., which we see described upon the ship's side, reaching from stem to stern, consists of this particle and innumerable others like it, all lying in the surface of the water, and all finding themselves at different places along the line.

OCEAN WAVES AND TRANSVERSE WAVES CONTRASTED.

Let us compare the sea wave on the one hand, and the transverse wave system on the other hand, and try to see (*a*) in what respects they resemble each other, (*b*) in what respects they are different, and (*c*) how far their differences and their resemblances may bear upon the question of the source or sources of the energy of the bow wave. In making these comparisons let us keep the diagonal wave out of view altogether, save only to admit that some quantity of energy passes off in it sideways which we must entirely eliminate from the matter under consideration.

THE OCEAN WAVE DESCRIBED.

First let the ocean be perfectly smooth, and afterward let a gale spring up out of the west, and let the wind blow steadily from the west and raise a considerable sea, after which let the wind cease to blow. Then we shall have a series of very regular ocean waves rolling from west due east. Let the length of these waves from crest to crest be exactly the length found in one of William Froude's experiments,* viz: 115.8 feet, and let their speed be the speed which he fixes as due to an ocean wave of 115.8 feet in length, viz: 14.43 knots an hour.

Suppose we have two steamers which are capable of maintaining that speed precisely, even when they have something in tow. Out of thin plates of metal, riveted so as to make a plain surface, we cut the profile or sheer plan of a vessel whose length on the water line is equal to 115.8×4 feet, or 463.2 feet exactly. Since the metal is a mere thin sheet, the towing of it edgewise will raise no wave whatever. Now we get our two steamers into such position that each will head due east, being abreast of each other and some two hundred yards apart. We pass hawsers from the lowermast heads of one to the lowermast heads of the other, square across the interval; and to these hawsers we hang our profile or sheer plan of 463.3 feet in length. Of course the seamanship of this maneuver is not very good; but we are only

* Paper of March 23, 1877, Trans. Inst. Nav. Arch., had undoubtedly in mind by R. E. Froude, April 8, 1881, in the paper in which he gets, for the casting up of the bow wave, half the energy from the transverse waves which follow in its train.

making an experiment. The steamers now steam due east at 14.43 knots an hour, towing the profile at that speed. The profile stands up straight like a ship, and the bottom of it reaches lower than the troughs of the waves, and the top of it reaches higher than their crests. We now have there, described upon the profile, the outline of a series of ocean waves, four in number, plain in sight, just as when a four-membered transverse system is described on a vessel's side. Since the profile is going exactly as fast as the waves, the outline of both crests and hollows remains steady and fast there, just as if it were glued to the metal. The profile, indeed, is moving east at 14.43 knots an hour, but the wave forms are moving east at just that speed, and so they keep up with the moving profile. To all intents and purposes this profile is a ship, save that it has no spread of the bows and has, in fact, no beam, and therefore it is not making any waves whatever. The ocean waves which accompany her have very nearly the look of the waves she would be making if she were a real ship and were going at just that speed, and the sea were perfectly smooth. There we see the series of ocean waves, with their crowns tucked up above the copper line, and their hollows tucked down below the copper line, exactly as if they were nailed to her, and exactly as if it were a series of transverse waves which she had kicked up in a perfectly smooth sea. Here we sketch roughly the profile ship, and the waves accompanying her, the latter all numbered for identification. We omit all diagonal waves, of course.

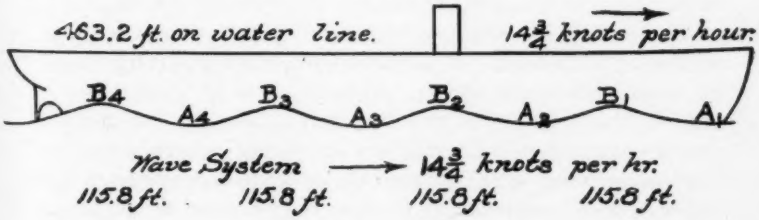


Fig. 2.

The reason why the waves travel on with the profile and keep up with it, rolling through the water just as fast as the profile, is found in the circular motion which each particle of water is having. This circular motion wheels or trundles forward the form and energy (but not the substance) of the wave, in the same manner in which a hoop snake is said to get over the ground when it is excited. The swell or rise of the wave is simply the upper half of the circle in evidence, and the swale or trough is simply the lower half of it in evidence. The middle of the after face or surface of the wave shows where a particle in that part of its surface is sinking plumb. The middle of the forward face shows where a particle there is rising bolt upright. The crown shows where a particle occupying that position is rushing onward, and the trough shows where an occupant of that position is surging backward.

No water mass is moving onward. It is merely that water particles are moving *in* the circle, and that the circle, minus the water, is advancing. Now a mere circle is nothing but an empty form, and for an empty form to be transported forward without any particles being also transported forward, means merely that particle after particle (or, more literally, particle before particle) is undergoing a circular motion, and that after a particle has got the top of its promotion, and whilst it prepares to begin to sink, the particle next forward of it gets to the top of *its* promotion and prepares to sink like the other. The wave substance stays and wheels over and over; the wave form gallops on, and a certain wave energy rides the form, and the speed of the two is the swiftness with which the particles succeed each other in vaulting to the top of the wave. It is just as when children pass the "tag" or touch from one to another through a line of children, all of whom, however, may be standing fast. The "tag" is energy, and wave energy is substantially a strong tag or push along the line of particles. For instance, the water that lies beneath the form $A^3\ B^2\ A^2$, regarded as forming a portion of a real ocean system, will not advance further. But the highest point or crest B^2 will advance with the ship, because particles in advance of the particle which at this instant is at the crest, will at later

instants climb successively up to the crest. Thus the slope B^2 A^2 will flit forward, and a moment later will be where at this moment the slope B^1 A^1 is, while the slope B^3 A^3 will meanwhile have flitted to just where the slope B^2 A^2 now is seen.

How the energy rides onward and with how powerful a stride, may be seen from the force with which the form B^1 A^1 knocks upward anything it may meet as the water in it rises, and from the force with which the on-surging water hurls itself upon whatever opposes it. Of course, and without shadow of a doubt, this wave will catch up any mass it finds in front of it, as, for example, the mass of peaceful and unsuspecting water just ahead of the point A^1, and will heave this up and dash it down again to the water bed. But if the water ahead *belongs to the company and trains with it already*, the wave energy will simply ride through it with cheer and with fresh encouragement.

THE TRANSVERSE WAVE MASQUERADES AS AN OCEAN WAVE.

(Expose the stub folder at the end of this paper.)

In my repertoire I have two figures like this Fig. 2. They are exactly alike, though I do not feel sure that either is very exact. One of them represents the thin sheet of metal in tow, and represents a following sea of mere rollers, without a breath of wind blowing, just as above described. The other is a picture, in elevation, of a real ship 463.2 feet long, of just the same profile or sheer plan as the preceding. She is making 14.43 knots an hour, and with her own steam, no wind blowing, and in a perfectly smooth sea. She is throwing up four transverse waves along her side, of just the length of the ocean waves in the other figure; the system looking as like the other system as two peas do to each other, except that there is now no "trough" just forward of the bow. By giving her bows (which, by the way, are unusually sharp) a certain peculiar shape I have so far eliminated the diagonal wave that it is no longer an embarrassment; some persons may doubt whether this is possible, yet no person who is thoroughly acquainted with model-making. Therefore I ask that Fig. 2 above may be suffered to stand for the outline of this real ship and of her transverse wave

system, although the "trough" which is just forward of the bow ought not now to be there, and should be excluded from the representation.

And here at the bow, with the transverse system, is one of those places in which it is at first almost impossible that one should not fall into error, and is one of those places where his eyes will almost certainly mislead him. I think we have here an admirable example of that omnipresent wit-beswindling and that everlasting thimble-rig of the senses, which always and inevitably constitutes the matrix or reciprocally-concave mould for the casting of every true understanding of a matter; a matrix which indeed nourishes (yet also overlies and conceals) the truth as long as the truth is indeed in conception, but has not yet been fully brought forth to the light.

Because the transverse system has the form and look of an ocean-roller system; because it has the length and height and speed of such a system; because it keeps lock-step with the ship as the ship might keep step with the rollers if she should reach a true roller speed; and, above all, because the system seems to lay hold of the peaceful water just forward of the bow with the same contemptuous energy with which an ocean troop would lay hold of any still surface which it might find in front of it—therefore, and by virtue of this mere show or seeming, the transverse system is presumed by the eye to be inwardly *as* the ocean-roller system, and to possess all the bounding vigor of that system; whereas the simple fact is, the transverse system is the dullest and most spiritless wave-commotion that can possibly be produced. Instead of being a form that is careering magnificently onward, it only clambers up as best it may, in seeking to escape the bow which is perpetually flogging it on; in lieu of galloping forward it must ever be dragged at the heels; in fact, it will not march a step of the way, but stands now on one foot and now on the other, and simply marks time. We shall see this plainly enough.

DETECTION OF THE IMPOSTURE.

Closely observing Fig. 2, I take a pen in my left hand, with some particles of ink on the pen, and I put the point of the pen

at A^1. I lay hold of the paper with my right hand. Then, all at the same time, I move the pen straight up and down with my left hand continually, and with the right I move the paper, with the ship's picture upon it, continually to the right and horizontally. As long as I do this, the motion of the pen, which is up and down continually, and the motion of the picture, which is horizontal to the right continually, will, between the two, leave a particle of ink at each successive point along the ship's side at the surface of the water, and will leave the particle of ink there at just the instant when, and at just the place where, in the up-and-down movement of the particle of water, each successive point in the picture of the ship's side will be reaching the particle. Thus the various particles of ink, successively left upon the paper, will describe the outline A^1, B^1, A^2, B^2, etc., etc., and will represent all those various particles of real water which lie in the surface alongside the vessel and which find themselves at various points in the line.

Now the straightforward energy of my right hand is playing the part of the ship's engines, and the energy of my left hand as it moves up and down merely, is playing the part of gravity which acts upon the ship-waves. The outline is an undulating one because it is the resultant of two motions, or rather of three motions, of which a pair are reciprocal. The ship on paper and the ship on sea are moving horizontally toward the right. The pen at A^1 and the particle of water at A^1 move straight upward. The combination of the two movements makes the up-slanting line A^1 B^1. The leftward or sternward component of this slant is not in the least traceable to the pen or to the particle in the sea. This component is the result of the motion of the paper in the picture or of the real ship on the water—in both cases a motion toward the right.

The down-slanting line B^1 A^2, composed of a straight-down element and a horizontal leftward element, is the result of the straight-down motion of the pen moved by my hand and of the particle in the sea moved by gravity, on the one hand, and of the horizontal motion of the paper ship and the real ship toward the right.

The reason why the line is curved instead of tooth-shaped or jagged, albeit the components of it are perfectly straight and lie right-angled to each other, is as follows:—In moving the pen perpendicularly down and up I imitate as closely as possible the varying motion of gravity, according to which are caused the risings and the fallings of our particle and of its accompanying cork or bottle. At B^1 they are at a pause; the ship is moving horizontally to the right, and therefore the line, for a very short length of it, leads horizontally to the left. The cork and the particle then begin to fall, yet slowly at the very first, as everything does which gravity takes hold of. The ship continues her speed to the right; hence the line slants a little downward. The particles now are falling more rapidly, as gravity requires; therefore the line now begins to slant more downward. Until they are half way down they are falling faster and faster, so until then the line slants more and more downward. Presently, as they, or rather the particles underneath them, begin to fetch up on the water-bed, by reason of the reaction of other particles of water whose gravity has become disturbed by the fall, their downward motion becomes feebler, and therefore the line now has less and less of a vertical component. At last they fall no longer; the ship's motion to the right becomes the only motion, and the outline therefore a horizontal one leading due leftward or sternward. At this stage, the gravity of other particles of water which have been disturbed and forced upward by the fall of these, begins to tell upon the particle and the cork, and this gravity now forces them up again, slowly indeed at the outset; wherefore now the outline, though it does slant upward, slants only a little. Their upward motion begins to grow, while the ship's horizontal motion continues steady as before; thus the upward slant begins to be more pronounced. An instant later the upward motion begins to dwindle; and since the ship's horizontal motion remains undiminished, the line begins to grow toward the horizontal, and perfectly horizontal it becomes by the time the cork and particle reach B^2.

Thus, in short, the cork and particle to all appearances are

making an up-hill and down-dale track toward the rear, and even continuing it far astern. The truth, however, is that they simply sink and rise, with a motion that is swiftest near the middle of each movement, and that fades away as they reach the top and bottom. The motion of the ship meanwhile being steady, and her form being rigid, the forward progress of each part of her side, where the wave outline is progressing also, is steady. The resultant of these two motions, the one a continued up-and-down motion of every particle of water, and the other a steady horizontal motion of every part of her side, is a see-saw (but rounded) outline of the water's surface composed of particles heaving up and down, each of them taking its regular turn in rising and in falling. The outline is a rounded or gently waving one instead of a jagged, because in their sinking and their climbing, and in their ceasing from each motion successively, their change as to motion is always gradual, and all this gives to the outline its easy curves instead of the sudden breaks which otherwise would distinguish it. In the outline their up-and-down motions are perfectly disguised by a merger into the concurrent horizontal movement of every spot on the ship's side with which the eye brings them into relation, as also by the circumstance that each particle in the surface whilst it is falling is in a position diagonally downward and abaft of another later-falling particle; abaft it, because it has always been abaft, and downward from it because it was beforehand in reaching the apex, and began sooner its fall and has longer been falling, and therefore has fallen farther; thus the after outline of the wave is a sinking and sternward-sloping outline. At the same time it is an outline that moves forward, because the apex B^1, situated at the critical point of the bow, is moving forward. In this manner, as to external appearance, the back of it appears like the back of an ocean wave. And for the same reasons, conversely applied, the front of it appears like the front of an ocean wave. But the two waves, ocean and transverse, are utterly unlike in character. The likeness of appearance is the sense-illusion of which I have spoken. The cognizance of their internal difference is a truth which underlies the fallacy of the senses.

THE IMPOSITION ILLUSTRATED.

The process of the manufacture of the transverse train can be illustrated perfectly as follows: On glass or on transparent paper, describe in ink a wavy outline to represent the transverse system. On a separate sheet of ordinary paper draw a perpendicular line in ink. Place the glass or transparent paper so as to overlie the other, with the general lay of the wavy outline at right angles with the perpendicular line. The perpendicular line is visible through the transparent paper. Its intersection with the wavy outline is also visible.

Now move the transparent or wavy outline paper from left to right, holding still and fast the perpendicular-line paper which is beneath it. The wavy outline thus caused to progress to the right will represent the steady march of the transverse system as seen marked along the starboard side of a ship in motion. The up-and-down line, on the other hand, is the line of the force of gravity acting upon each particle of water, whether downward, in obedience to gravity acting directly upon *it*, or upward in rebound from other particles whose gravity has been disturbed by its fall. The point of intersection between the wavy line and the up and down one marks the position of any surface particle. Whilst we are moving the transparent paper sideways, if we follow this point of intersection as it travels up and down the perpendicular line, and sidles aft along the wavy line, we see represented the total history of the various movements of any and every particle in the surface. For the particles there are all alike, and behave alike, each taking its turn in a really merely up-and-down movement, whilst still maintaining its part in forming the total wavy surface.

DOINGS BENEATH THE SURFACE.

It is unnecessary to consider the motion of particles in lower strata, since these merely constitute corresponding layers in deeper water, and behave almost the same as the uppermost layer. Only in general it is to be remembered that, roughly speaking, whilst a lot of particles are sinking into the forward part of the trough, more room is being made abaft in the water

bed, from the after part of the trough, by another lot of particles situated next abaft the former lot. This second or after lot is rising by virtue of the almost-just-now disturbed, and absolutely just-now reasserted, gravity of other water into which it had fallen an instant earlier; and this after or more sternward lot is also *helped* to rise by a certain further impulse (let us examine it later) which comes, transmitted through other water, from the energy developed by the first lot in its fall. This helping energy takes effect in a sternward, and not in a bow-ward direction, for the reason that next to it, between it and the bow, and on a higher plane, there is falling at this instant, as we know, a third lot of particles, and the energy of *that* lot has a downward drive, against which the energy of the middle lot will not make head, but will rather go toward the lot which lies abaft, where already there is a decided yielding.

THE ENERGY COUNTERMARCHES QUASI-STERNWARD.

Thus it may be said without error that there is a continuous current of energy passing down and up, and withal sternward, with countermarching in vertical plane, along successive vertical sections of falling and rising particles; which current of energy consists not only of that energy which is inherent in the substances there in motion, but which, over and above this, consists of an energy laid on in fresh increments from forward, from fresh waves generated ahead, and transmitted sternward continuously *through* the moving substances, and, as it were, outstripping their several alternate motions. We say "sternward," but this, for the most part, is relatively speaking: the principal thing is to recognize that in any mass of these vibrating particles, the energy already acquired by them and which is being lost by friction, etc., gets steadily reinforced by a supply had from particles found next bow-ward which are in younger and more vigorous vibration.

Thus it appears that while the waning energy of the ocean wave which earlier we were considering, gets reinforcement from the wave behind it, the waning energy of a transverse ship-wave, on the contrary, is reinforced from the wave in front of it. This last is easily seen to be the case from the circumstance that when

first noticeable, when the ship is just beginning to move, *it is the bow wave that is created first of all.* Not until an instant later are other waves seen abaft it; from this circumstance it becomes evident that the waves abaft it are only its echoes or reverberations; that is to say, are echoes and reverberations of bow-wave masses thrown up in steady procession during instants prior to the instant at which was thrown up the bow wave at this instant visible in the van.

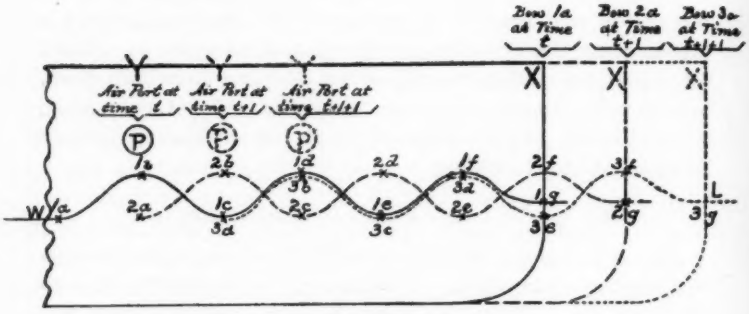


Fig. 3.

But the process can be made plainer by help of a diagram.

In Fig. 3 let YX be the forward portion of a vessel moving through the water. In this figure I magnify greatly the height of the waves, although such waves can really be produced by appropriate lines in the shaping of the vessel, and by moving her at the proper speed. But since the constitution of all transverse ship-waves is the same, the only effect of exaggerating the height of the waves is to make the details of wave-making somewhat plainer to the eye.

In this figure we see full lines, broken lines and dot lines.

The full ones stand for the vessel and her position at a certain instant which we will call the instant *t;* they stand also for the surface of the water along her side as seen at the same instant.

The broken ones stand for the same vessel when she has reached a spot half a wave's length farther forward, which spot

she reaches at the instant $t + 1$; they stand also for the water as it appears at this instant.

The dot lines stand for the same vessel when she has reached a spot which is a wave's length ahead of the first spot; this spot she reaches at the time $t + 1 + 1$; they also stand for the water in the position in which it finds itself at this latest instant.

In order to avoid confusion, we suppress entirely the scantling or diagonal wave. This suppression does not affect the character of the transverse waves; for that matter, it is easy to shape a model so that her diagonal wave will at least be imperceptible. The waves, as they have been called, or the "wavings" as perhaps they ought to be called, march steadily with the ship; and the outline of each of them stays in its own place just as if the whole outline had been triced up to bolts, and lashed down to bolts, driven into the ship's side at the crowns and troughs of the waves.

HOW THE WAVINGS MARCH WITH THE SHIP.

No. 2 of the wave system at the time t,—No. 2 consists of the particles which lie below the outline $1a1b1c$, being particles lying between that outline and deep water—has now its crown at $1b$, or directly under the air-port P, which is beneath the inscription, "Air-port at time t."

At an instant later, viz., at $t + 1$, the vessel will have moved half a wave's length forward, and the *broken* perpendicular line will show the new location of her stem; and when she shall have moved another half wave's length, which will happen at $t + 1 + 1$, the new location of her stem will be indicated by the perpendicular dot line seen further ahead.*

This ship has but one air-port. Its location at the instant t may be seen directly under the words, "Air-port at time t." At $t + 1$ it is under the words, "Air-port at time $t + 1$," and at $t + 1 + 1$, it is under the words, "Air-port at the time $t + 1 + 1$."

Each "waving," as we may call the water-elevation, advances its position exactly as fast as the various parts of the ship advance theirs. At the instant t, the waving which at that instant

* Expose the stub folder at the end of this paper.

is the third of the series, is found with its surface particles forming the full outline 1*a*1*b*1*c*; and at $t + 1$, the waving which at that instant is the third of the freshly-existing series, is found with its surface particles forming the broken outline 2*a*2*b*2*c*. At $t + 1 + 1$, the waving which at that instant is the third of the still more newly-presented series, is found with its surface particles forming the dot-outline 3*a*3*b*3*c*.

At $t + 1 + 1$, the ship having advanced a whole waving's length, the position of the outline of the third waving, viz: 3*a*3*b*3*c*, is identical with the position of the outline 1*c*1*d*1*e* of the *second* waving of the system exhibited by her at two instants ago when she was farther to the rear; the two wavings themselves are identical and take place in one and the same set of particles. And at this present moment the outline of the second waving (as the train now stands), viz: 3*c*3*d*3*e*, is identical with the outline 1*e*1*f*1*g* of the bow wave in the system as it stood two instants ago, viz: at the time t, and the two wavings themselves are identical, except as to the front half (1*f*1*g*) of the outline 1*e*1*f*1*g*, in respect which we must note that when the bow enters the undisturbed water ahead it finds this water at the normal level instead of the lower level on which the troughs are found.

It will happen, then, that in any series the waving which stands third in it will have the same outline, and will exist in the same particles of water, as the waving which stood second in the next earlier series. The same will be the case between the waving which stands second in any series and that which stood foremost in the earlier series, except that the foremost waving, being the bow wave, carries no trough ahead of it. For ahead of it the water is merely at normal level, which is half a wave height higher than a trough.

In the first or bow wave, 3*e*3*f*3*g*, the particles lying plumb beneath 3*e*3*f*, in falling perpendicularly, throw some of their energy into particles lying in the water bed and disturb the gravity of those particles. When the gravity of the latter recovers itself, the falling particles just mentioned are thereby hoisted up again and are found under 3*d*3*e*, becoming the front

half of the second wave in the series next later created, of which later-created series the leading member, as we see, will rear itself one wave length farther ahead in the line. The rest of the energy of the falling particles lying beneath 3*e*3*f* is played by them upon or into the particles lying beneath 3*d*3*e* abaft them, and the particles under 3*d*3*e* are helped perpendicularly up by the perpendicular fall of the former. This is done by the reasserted gravity of still other particles which have been disturbed by the falling particles lying beneath 3*e*3*f*. The particles 3*c*3*d*3*e*, whose front division is now being encouraged upward, are really no other than our old friend the bow wave who was holding his head still higher just two instants earlier, when the ship was a wave length farther aft and he was the leading wave of all.

WHY THE WAVINGS MARCH WITH THE SHIP.

The undulation marches on in the following fashion :

As the ship moves ahead, the outline 1*a*1*b* (constituting the rear face of the waving 1*a*1*b*1*c*) has all its particles falling perpendicularly; and the outline 1*b*1*c*, constituting the *front* face of the waving, has all its particles rising perpendicularly. The point 1*b* marked upon the ship is the *critical point*, by which is meant that at just this point in the ship's side the particles in the front face of the wave successively cease to be rising, and thereby cease to be constituting the front face, as 1*b*1*c*, but begin to fall and thereby begin to constitute the rear face, as 1*b*1*a*. By this constant falling of the particles which are at the rear, and constant rising of the particles which are at the front, and constant and ship-accompanying movement of the point where a particle ceases to belong to the front and begins to belong to the rear face, it comes about that both the front and rear outlines travel steadily on with the ship. This travel of outline will happen just as it happens with an undulation of any long rope of convenient thickness, held with tension neither taut nor slack, between two persons. If the person in the rear gives the rope a simple jerk downward, an outline of wave depression will travel forward the whole length of the rope. If, however, he swiftly follows the down jerk with an up jerk, a wave outline of depres-

sion, conjoined with a following elevation, will travel forward; and if he continues to jerk the end up and down, the rope will show a series of wave outlines of depression and elevation.

But, except as to the mere process of wave marching, the rope illustration is misleading; for the rope gets its outline-producing energy applied at the point from which the march advances, and the energy developed progresses with and along the march. With the transverse series of waves, on the contrary, the outline-producing energy is applied steadily *at the van*, and the troopers catch up from the van the undulation, and they maintain it by virtue of gravity, alternately active and reactive, the column meanwhile marching and keeping exact distance.

A TEST OF THE DRIFT OF ENERGY.

On one side of the top of a bucket we fasten a special lip, contrived for pouring water out of it in an easy flow. Let the edge of this lip be straight, and let it be tangent to the circumference of the top, so that the water in being poured will fall straight-edged, as if over a mill dam. We take a trough and nearly fill it with water, and we fill the bucket also. Holding the bucket above the trough and close down to it, we walk along and pour out water into the trough, letting it merely fall as we advance. Following the fall, and advancing as we advance, we shall see an undulation, and in an instant we shall see more undulations behind that one, all marching along behind the bucket, and keeping due distance. The foremost undulation of the train is the rebound of the outpoured water, or—just as good—of water displaced by it; and the second undulation is the first rebound of the first undulation. Now the water in coming out of the bucket and falling as it comes, behaves exactly like the falling water in the after half of the transverse bow wave. The undulations which the bucket trails along behind it are exactly in the condition of those members of the transverse train which follow the bow wave. Those members have no more part in raising the bow wave than these undulations have had in getting the water originally into the bucket.

The ship has no bucket forward there, and no reservoir of

raised water. She raises the water steadily as she goes, and she steadily drops it again at the critical point of the bow. Her process of wave-making without any reservoir is essentially the same as was our process with a reservoir.

A BETTER TEST AS TO THE DRIFT OF ENERGY.

For that matter, instead of a bucket, take a flat-based, perpendicular-sided, round-topped piece of wood, shaped like the uppermost third of a steamer's paddle box, and halve it by a transverse perpendicular cut from crown to base. One of the halves we drag through the water, near the surface, rounded side upward and forward, letting the water pile up in front and over the crown and fall abaft the crown, and create a train of waves that follows along behind.

BUT THE BEST TEST IS THE FACT ITSELF.

It may seem as if the work thus done were not quite analogous to the work of the ship's bow in producing the transverse bow wave, because the wave is begotten *above* the rude model instead of along its side. Therefore let us turn the plane of the model ninety degrees sideways, and have the round part at the side instead of at top. If we force this through the water, the round part foremost, we shall be making waves upon at least one side of it. They will be like the waves made by this same piece of wood in its former position, only they will be of water which has been lifted by being caught between the rounded surface and other water lying *to one side*, whereas in the other case they were of water which had been lifted by being caught between the rounded surface and other water lying *ahead*. In both cases alike it is evident that the fall of the water from the wave height to which it has been raised is an event which is subsequent to the raising and cannot aid the raising, but will result in a consequent rebounding or echo.

SEEK CHARACTER WITHIN AND NOT ON THE OUTSIDE.

The essential difference, then, between the transverse system and the ocean system—the latter system being taken as consisting of rollers running in a perfect calm, yet advancing (let us suppose it) into undisturbed water—is as follows:

While the two are substantially alike in profile, and alike in the onward movement of profile; alike also in adding to their length at the van of the column only; alike moreover in effecting this addition by means of energy applied at the van; alike, in short, as to every feature which the eye can note—or can note in water on which no objects are floating—while alike in all these outward respects, they are wholly opposite in all inward and essential ones. Instead of transmitting, *from behind*, the energy for maintaining and carrying forward the system, passing the energy through the system, as the ocean wave does always, the transverse system applies *at the front* a fresh energy created at the front; and then, leaving the new wave and its energy to dance up and down in the spot where created, it marches on and repeats the process with a fresh mass of water and a freshly created energy.

PROFESSOR LAMB'S SCHOLIUM.

The doctrine of Professor Lamb appears to call for further discussion.

It relates to the case where the transverse system consists of a bow crest and a stern crest, with a solitary depression between them; and his suggestion is that in this case there is really no loss of energy from wave making.

Here the rising of the echo of the bow wave becomes coincident with the rising of the stern wave. The rising of any stern wave whatsoever means the diversion, into a useless hoisting of water there, of energy which should have been applied in pressure upon the up-and-aft-and-outboard-sloping immersed skin of the afterbody, in order to twinge the vessel with a forward pressure. In Professor Lamb's, case, however, the bow wave echo makes confederation with this insurgent water. Thereby the echo not merely increases the waste by its own store of energy, but also applies that energy in opposition to whatever beneficent forces may be operating at the stern.

In order to restore to the ship the energy which the ship has put into the bow wave, the echo of this wave ought to bring its particles to apply the momentum of their up-motion against the rising bottom and convergent sides of the afterbody, along the

run, at that place of hollow, half-hearted urgency and insistence on the part of the now confluent superficial streams, where as yet they are not willing to flow promptly inboard as they ought, but negligently leave a depression there instead of establishing a positive and helpful pressure. In Professor Lamb's stern-wave case, on the contrary, the treacherous echo does, in fact, along the run, in the region of depression, just before it confederates with the stern wave proper, set the energy of its now down-moving particles at work, destroying, as far as they are able to do, the good effects of the streams of lower strata which, ever faithful to their labor, and impressed (through the instrumentality of surrounding water) with the gravity of the occasion, are thrusting upward with all their might against the rising bottom of the afterbody.

The case in which there is no loss of energy by a transverse bow wave, save loss by internal friction and external dispersion of itself and echo, is where the up-motion of the particles of the echo takes place in the spot of *subsidence in front of the stern wave*, and fills up all depression there. For it is the reaction from this depression that causes the elevation of the stern wave. If the bow-wave echo removes the depression, the water preserves an even bearing, and no stern wave whatever is created. And if no stern wave, it means that the immersed surface of the afterbody is receiving as much bow-ward pressing energy from the stern water, as the forebody is receiving of sternward-pressing energy from the bow water; excepting, however, all losses by the diverging wave and by friction in casting up the bow wave, and by internal friction and outboard dispersion in the echo during the time it takes the stern to advance to the spot where the previous bow wave is performing a reverberation. Perhaps a perfect level at the stern, and not a rise of water there, is what Professor Lamb has really in mind, although he speaks of an "elevation of the water at *each* of the former points," *i. e.*, at the bow and the stern, as an elevation which "causes no loss of energy." For it is clear that with these two elevations we must have two distinct and complete losses; while in a single bow wave with absence of stern wave we have no loss (save as above

excepted), because the energy expended in hoisting water against the forebody is returned to the ship by the later thrust of the echo of the same hoisted water, a thrust which presses against the rising and narrowing under-surface of the afterbody. But if Professor Lamb's contention were literally true, it would be *without any expenditure of energy* that the ship would be performing the work of raising both these elevations as well as the resulting echoes astern.

THE CONDITIONS AT THE TWO ENDS ARE OPPOSITE BUT SYMMETRICAL.

Concerning the stern wave it may rightly be said that all, or nearly all, the things which are true of the bow wave are true of it, yet with reversedly symmetrical parallelism. Many matters relating to the one wave which at the first may appear inexplicable, become quite simple when illustrated by things observable in the other. If we light upon a mysterious phenomenon at one end of the ship it behooves us to turn to the other end, where we shall probably find the explanation. It seems, indeed, as if the inevitable bewildering and the chronic sense-illusion which attach to all sensuous phenomena, could, in this field at least, be themselves eluded, and as if, by means of this interchange the habitual sense-inversion were in fact converted into a straightforward and normal impression.

A SIMPLE PHENOMENON.

A phenomenon to which no reference has thus far been made may perhaps confuse the experimenter, and may seem at first to militate against some of the foregoing observations.

If, during the propagation of a powerful transverse train, the model be stopped upon the instant, the train will still move forward. In this occurrence the beginner will naturally (and in conformity with the customary sense-illusion), suppose he beholds a confirmation of the theory that the transverse wave gets a part of its energy from the train behind it.

The cause of this continued on-rush is as follows: The water in front of and beside the bow can by no means be elevated against the force of gravity, except by a pushing of its particles forward; in the course of which forward-pushing it happens that

certain underlying particles underrun certain other particles which belong to the more nearly superficial strata, and in which those superficial particles ride the deeper lying ones. Thence it comes about that whilst in the deeper strata there exists a general leisurely forward and outboard movement of lower strata pressed forward and outboard by the vessel's progress—by forward I mean in the direction of the vessel's progress—there is taking place in the upper strata a sudden forward and outboard transportation of the more superficial water which the bow is ever encountering and crowding very brusquely into those directions.

CAUSE OF THE STERNWARD DEFLECTION OF THE TRANSVERSE TROOPERS.

It may therefore be rightly said that the transverse train consists of water which possesses a degree of forward motion—forward, relatively to the outboard quiet water. The continual forward shove of the spreading contour of the bows produces a forward set along the vessel's side. Here, too, seems to be found the proper explanation of the observable sternward deflection of each member of the transverse system at its outboard end. This deflection William Froude sought to explain on the ground that "when a wave is entering undisturbed water its progress is a little retarded, and it has to deflect itself into an oblique position so that its oblique progress shall enable it exactly to keep pace with the ship." (*Parallel Middlebody*, Trans. I. N. A., 1877.) This is true in a way, yet not in the way which I think William Froude had in mind. The "progress" he was thinking of was to be a progress *qua* wave, a progress of motion and not a transportation of substance. The progress which really exists there and which gives the members of the transverse system an oblique deflection is a progress *qua* water, a forward transportation of the particles. The inboard portion of the wave or reverberation is situated in a portion of the forward-moving current which has a stronger forward set than has the more outboard portion. These reverberations or echoes do not revolve or roll forward; they merely dance up and down; and the lagging of their outboard ends is simply the result of outboard spread or extension

(effected through friction between original echo water and the next outboard water) of the motion of reverberation, communicating itself to water possessing less forward impetus than is possessed by the water in which the reverberation first began.

ULTIMATE STRETCHING OF THE ECHOES.

Now this onward motion of the water in which the transverse waves, or rather wavings, are in operation, is one which it will retain for a considerable time, and which in disappearing will be lost only by degrees, viz: in proportion as it gets farther and farther aft and farther and farther astern. The loss of this forward set or push will result in a slight lengthening of the echoes, measured from hollow to hollow, as they reach farther and farther astern. This lengthening will in part, however, be the result of a different cause, viz: the gradual dissipation, sternward no less than transversely, of a slight amount of quasi-potential energy existing in the system, and in part it will be the result of a third cause which it is not necessary to discuss in this connection.

If the water movements have now been correctly described, it follows that the formulas of the commentators are in error, and that the ship's engines are obliged to furnish the whole of the energy which enters into and throws up the bow wave. All of this is sheer waste save so much as can be recovered along the afterbody or at the stern.

THE MATTER IS A PRACTICAL ONE.

Respecting the bow wave and its formation, there are several facts which bear specially upon the problems of ship design for speed and for burden; and which it may therefore be interesting to consider at a future time. The first or opening measure to be taken in all real reformation is necessarily in the nature of pruning and purgation. Healthy growth is, of course, a subsequent process.

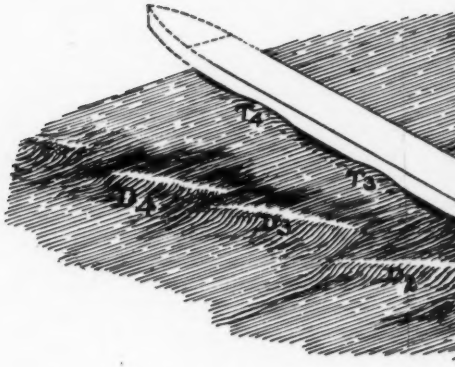

T4
T3
T2
T1
D4
D3
D2
D1

Fig.

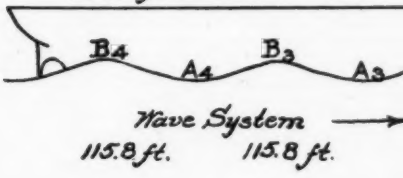

463.2 ft. on water line.
B4
A4
B3
A3
Wave System
115.8 ft.
115.8 ft.

Fig.

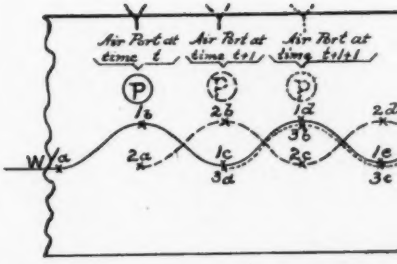

Air Port at time t
Air Port at time t+1
Air Port at time t+1+1
P
W
1a
2a
1b
2b
3b
1c
2c
3c
3d
1d
2d
1e

Fig.

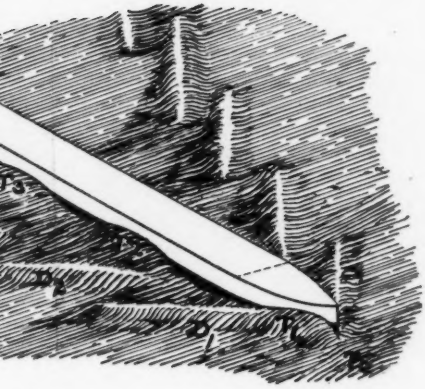


Fig. 1.

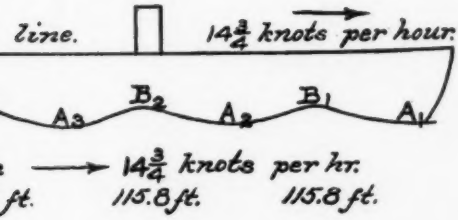


Fig. 2.

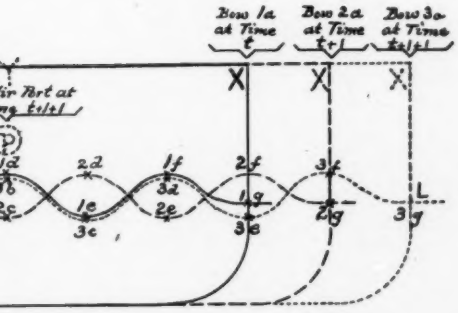


Fig. 3.

SOME EXPERIMENTS HAVING REFERENCE TO THE DURABILITY OF WATER-TUBE BOILERS.*

By A. F. Yarrow.

Feeling sure that anything which may tend to increase the durability of water-tube boilers will interest the members of our Institution, I have much pleasure in laying before you the results of some experiments which we have recently carried out with a view to ascertain the comparative merits of nickel-steel tubes and tubes of mild steel, such as have hitherto been used in water-tube boilers. The nickel-steel to which this paper refers is an alloy, having from 20 to 25 per cent. of nickel, and in these experiments we have tried to repeat as nearly as possible the worst conditions as regards wear and tear to which tubes in water-tube boilers are subjected.

The deterioration of the tubes is probably owing (1) to the action of acids in the water, due to grease, which in spite of every precaution, finds its way to the boiler; (2) to the tubes becoming overheated and oxidizing on the outside, through contact with the hot gases when passing from the furnace to the uptake; (3) to the action of the steam, which, if superheated, decomposes, causing deterioration on the inside of the tubes. The last two conditions occur when the tubes, from defective circulation, shortness of water or from the collection of scale, become overheated.

Table I records what we have termed the "corrosion test." It will be seen that the piece of nickel-steel tube A was compared with the piece of mild-steel tube B, the original weights of which were 190 and 186 grammes respectively. Both the tubes were immersed in the same dilute solution of hydrochloric acid for various periods, as indicated. The duration of the tests varied, as shown, from 21 to 168 hours, making a total number

* Read at the July meeting of the Institution of Naval Architects. [In reprinting this article several figures have been omitted.—Ed.]

of hours for all the trials of 533. The ultimate loss of weight in the nickel-steel tube was 5 grammes, and in the mild-steel tube, 98 grammes. It will be seen that the original weights of the two specimens in this case did not accurately agree; but in the second trial, E and F, the tubes were of the same original weight, namely, 188 grammes each. The ultimate loss of weight was found to be 7 grammes with the nickel-steel tube E, and 100 grammes with the mild-steel tube F.

TABLE I.—CORROSION TEST.—TO ASCERTAIN THE EFFECT OF ACID ON NICKEL-STEEL AND MILD-STEEL TUBES.

Marks and material.	Original weight. Grammes.	Two parts water, one part hydrochloric acid.									Total loss in weight during 533 hours.
		Duration of immersion in hours.									
		21	64	44	92	168	72	24	24	24	
		Weight in grammes at end of each period.									
Nickel-steel, A.....	190	190	189	189	188	186	186	185	185	185	5
Mild steel, B.....	186	184	173	166	140	101	98	94	91	88	98
Nickel-steel, E.....	188	188	187	187	186	183	182	181	181	181	7
Mild steel, F.....	188	187	173	162	137	112	95	92	90	88	100

The upshot of the above tests, it will be seen, is that the loss of weight in the first series of tests of the nickel-steel tube amounted to 5 grammes, being 2.63 per cent., and in the mild-steel tube to 98 grammes, being 52.68 per cent. In the second series of experiments the loss in weight of the nickel-steel tube was 7 grammes, being 3.72 per cent., and the mild-steel tube 100 grammes, being 53.19 per cent. The average loss of weight in the mild-steel tube was therefore sixteen and one-half times that what it was in the nickel-steel tube.

It may be contended that the relative corrosion of the two specimens when using dilute hydrochloric acid does not corre-

spond with what it would be with such acids as are present in boilers under working conditions, but it is not unreasonable to suppose that it may serve as a guide.

TABLE II.—FIRE TEST.—TO ASCERTAIN THE EFFECT OF FIRE ON NICKEL-STEEL AND MILD-STEEL TUBES.

Marks and material.		Original.	Heated blood red for thirty minutes and allowed to cool.	Heated bright red and cooled in water.	Scale removed.	Heated straw color for one hour and allowed to cool.	Tubes partly flattened to remove scale.	Heated straw color for one hour and allowed to cool. Scale removed.	Heated straw color for one hour and allowed to cool. Scale removed.	Heated one hour, straw color, and allowed to cool.	Scale removed.	Total loss in weight.
Nickel-steel, C.....	Wt. in grammes.	192	192	190	190	171	170	159	151	145	145	47
Mild steel, D.....		185	184	183	180	130	120	94	68	42	40	145
Nickel-steel, S.....		188	188	186	186	172	172	153	142	139	136	52
Mild steel, H.....		188	188	186	184	147	145	89	58	51	45	143

We will now turn to Table II, which records what we have termed the "fire test." This was conducted in the following way: Two tubes were placed side by side in a small brick furnace, where they were heated to the same extent, and in every way were practically under the same conditions. The loss of weight of each tube due to oxidization after they had been in a very heated state is indicated by the weights given. It will be seen that the original weight of the nickel-steel tube C was 192 grammes and of the mild-steel tube D was 185 grammes. The total loss of weight in this series of tests was, in the case of the nickel-steel tube, 47 grammes, or 24.47 per cent., and of the mild-steel tube, 145 grammes, or 78.37 per cent. In this case also the original weights of the two pieces of tube were not exactly the same, and we therefore repeated the experiment, as shown by G and H, in which the weights of the two tubes were

identical, namely, 188 grammes, and the loss of weight was found in the nickel-steel tube to be 52 grammes, or 27.66 per cent., and of the mild-steel tube, 143 grammes, or 76.06 per cent. The average loss of weight in the mild-steel tube was therefore 2.9 times what it was in the nickel-steel tube.

These results were submitted to Sir John Durston, and he pointed out that the experiments did not accurately conform to all the conditions under which boilers are worked, inasmuch as the tubes, in the case of a boiler when the heating surfaces are not in close contact with the water inside, are subject not only to the action of the gases on the outside, but to that of the superheated steam in the inside. The correctness of this view is unquestionable, and we consequently tested two tubes having a length of 1 foot 8⅝ inches by a diameter of 1 inch, outside by 14 L.S.G. This experiment we termed the "superheated steam test." The experiment was carried on in the following manner: Two tubes, one of nickel-steel and the other of mild steel, were placed side by side in a small brick furnace; at one end of each tube steam was supplied at 60 pounds pressure, it being allowed to issue slowly from the opposite end of each tube, thus ensuring the steam being highly superheated. The original weight of each tube was 612 grammes. After the experiment had proceeded ten hours, it was stopped, as the mild-steel tube gave out, steam issuing from the defective place. The loss of weight in the case of the nickel-steel tube was 12.7 grammes, and in that of the mild-steel tube 85.2 grammes. Deterioration in this case is due partly to the action of the steam inside the tube and partly to that of the gases outside.

The loss of weight of a boiler tube from deterioration at the commencement of its life being much less rapid than towards the end of its life, the loss of weight cannot be considered as a quantitative guide for durability, and we continued the superheated steam test as follows: After the mild-steel tube had burnt through and allowed the steam to escape, we replaced it by another similar mild-steel tube corresponding to what would be done in retubing a boiler. The experiment was then continued, and it was found this second mild-steel tube gave

way, and the steam burst through after eight hours, the nickel-steel tube still remaining intact. We then substituted this burnt mild-steel tube by another, and we found that after three hours the nickel-steel tube gave out. Every two hours during these experiments the position of the tubes was changed about, not only end for end, but side for side, so as to ensure that both tubes were subjected to the same conditions.

It will be seen from this that the durability of the nickel-steel tube corresponded to twenty-one hours, and the mean durability of the first two mild-steel tubes to nine hours. I think, therefore, that there is a probability that from this cause of deterioration a boiler would require to be retubed two-and-one-third times as often with mild-steel tubes as it would with nickel-steel tubes.

In the last experiment the tubes were heated to a bright red, and as it would be unwise to come to any conclusion based upon a single set of experiments, we repeated it in precisely the same manner, with the exception that the tubes were in this further test only heated up to a very dark red. They were, in this trial, 3 feet 6 inches in length. The result was similar in character to that obtained when the tubes were heated to a bright red, the only difference being that the trial lasted considerably longer, as the deterioration was not so rapid on account of the low temperature. The greater durability of the nickel-steel tube, as compared with those of mild steel, was fully confirmed. The nickel-steel tube lasted 2.8 times as long as one mild-steel tube, and twice as long as the other mild-steel tube. Both ends of the tubes were fitted with copper expansion pipes, the object of which was to allow the tubes to expand and contract freely.

It is a well-known fact that a mild-steel plate, or a mild-steel tube, when heated and cooled, becomes permanently reduced in length, and this fact must be borne in mind in boiler design, because frequent variations in temperature take place in a boiler, owing to the opening and closing of the fire door, and the constant varying intensity of the combustion. This permanent contraction during the life of a tube varies according to circum-

stances, but we thought it well to have some record of its extent when subject to the conditions under which the tubes were placed in this superheated steam test. During the life of one mild-steel tube, 3 feet 6 inches in length, heated twenty-one times to a dull red heat for periods of two hours' duration each, steam passing through the tube at a pressure of sixty pounds, its length was permanently reduced $\frac{56}{64}$ inch. The nickel-steel tube of the same length subject to the same conditions increased $\frac{14}{64}$ inch. The lengths were recorded every two hours, and the extent and periods at which the increase and reduction of length took place were clearly shown. Although, as I have said, it is a well-known fact that a mild-steel tube will diminish under these conditions, the extent to which this takes place is not perhaps generally known.

In the foregoing experiments the tubes were ungalvanized. Had the mild-steel tubes been galvanized there would have been a small addition to their durability, the extent of which is a matter of doubt.

We then made some trials with a view to ascertain the relative expansion by heat of the two materials. Two tubes were taken, 22 inches long, 1 inch in diameter, No. 16 L.S.G. They were inserted in a large tube and heated gradually up to a dull red up to about three-fifths of their length. The tubes were fastened together at one end and projected freely and independently beyond the furnace at the other. A record of expansion of each of the tubes was made by means of a trammel, and their expansion accurately determined. It was found that the expansion of the nickel-steel tube was considerably greater than that of the mild-steel tube. The process of heating up occupied 330 seconds, and it was found that the relative expansion was as 3 to 4, the nickel-steel expanding the most. The object of this experiment was to ascertain whether there was sufficient difference in the expansion and contraction of the two materials to cause trouble when nickel-steel tubes are placed within a group of mild-steel tubes. The result points to possible risk in this direction, and should it be desired to place nickel-

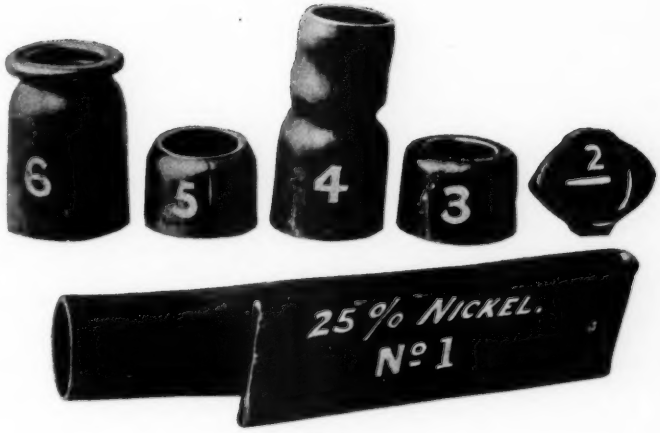


FIG. A.

FIG. B.

steel tubes in those parts of the boiler where deterioration proceeds with the greatest rapidity, and mild-steel tubes elsewhere, this variation of expansion should be borne in mind. I am not prepared to say that it is a source of risk; but it is one of those practical points which must not be overlooked.

To illustrate the suitability of nickel-steel from a mechanical point of view, I have brought a few specimens, see Fig. A, Nos. 1 to 6, to illustrate its ductility, which is almost equal to that obtainable with mild steel. I would submit that the ductility of these samples is amply sufficient for all practical purposes. Nickel-steel is considerably tougher in working than mild steel; it involves more labor, and causes greater wear and tear of the tools employed in expanding the bellmouthing, to which latter operation we have always attached the highest importance. The ductility does not seem to be impaired by sudden changes of temperature, as shown by specimens Nos. 7 and 8, Fig. B, these specimens having been bent after being repeatedly heated and chilled. The tools upon which our tests have been made were supplied, some by Messrs. Firth and some by Messrs. Krupp.

As regards cost, sufficient has not yet been done to know what the probable ultimate price will be, but, doubtless, it will be reduced from what it now is, if tubes of this alloy are introduced. Even at the present stage, judging from the experiments described, it is not unreasonable to expect that the longer life of the nickel-steel will prove fully proportionate to its higher price, if the cost of the more frequent replacing of the mild-steel tubes is taken into account; and, if this surmise is correct, clearly a decided gain would be obtained by the greater trustworthiness of boilers with nickel-steel tubes, and by avoiding the frequent loss of time involved in retubing operations, during which period the boiler is laid up.

I would observe that we have tried experiments as to the comparative durability of nickel-steel having small percentages of nickel, say up to 5 per cent., and have found that a very slight increase of durability is obtained by such alloys, but not sufficient to render them of any practical value for boiler tubes.

SUMMARY.

From the foregoing experiments I think it not unreasonable to assume that nickel-steel, 20 per cent. to 25 per cent., boiler tubes will have, as regards acid corrosion, a vastly longer life than those of mild steel, and, as regards the deterioration from the action of heated gases or steam, at least twice the durability of mild steel. Before concluding I would like to mention that these experiments have been carried out in consequence of our attention having been called to the possible advantages of nickel-steel tubes by Mr. Andreæ, the engineer-in-chief of the Dutch Navy.

THE LOGICAL ARRANGEMENT OF THE MOTIVE POWER OF WARSHIPS.*

By Rear Admiral George W. Melville, Engineer-in-Chief, U. S. Navy.

[While this paper was read in March last, and has been widely reprinted, either in whole or in part, both in this country and abroad, the Journal deems it of such importance that it takes this occasion to record it in full in its pages, being now able to include the complete discussion as well as the reply to the same by the author, Rear Admiral Melville. To this reply attention is particularly invited.—Ed.]

In the preparation of a set of tables showing the power required to drive a vessel of a given displacement at a given speed, data have been used which were gathered from the results of about two hundred trials of nearly as many ships. From this set of tables there was developed the remarkable fact that the propulsive efficiency of vessels with three screws is, in almost every case, above that of ships of approximately the same size, speed and general lines, but fitted with only two sets of engines. Attention has heretofore been drawn to the remarkable performance of the U. S. cruisers *Columbia* and *Minneapolis* on their trials. Recently, as the number of high-speed ships has increased so greatly, it has been very interesting to those who were responsible for the plans of the machinery of these cruisers to note how well they have maintained their position in the front rank of all naval vessels. These five-year-old ships, ten years old in design, are still among the most economical vessels in the world's navies as far as propulsive efficiency goes.

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*Read at the Fortieth Session of the Institution of Naval Architects, March 23, 1899; the Right Hon. the Earl of Hopetoun, G.C.M.G., President, in the Chair.

There are many reasons for the superiority of the *Columbia* and *Minneapolis* over other vessels of the U. S. Navy, built at about the same time. The stream lines of these ships are remarkably easy, and the resistance is low, these factors giving—it is claimed by many—a total resistance below that calculated from results of trials of less carefully-designed vessels. This is no doubt true to a certain extent, but comparison between these American ships and those of other nationality, but of approximately the same lines and speed, shows still the superior efficiency of these vessels. The main cause of this increased efficiency lies in the use of three engines and propellers for the motive power. Not only has the propulsive efficiency been benefitted, but there are so many engineering and tactical advantages arising from the use of triple screws that it may be readily seen why so many ships are now designed for this system of propulsion.

The advantages due to the use of three propelling engines, instead of two, have been pointed out before, but it may be of interest to recall some of the reasons leading to the adoption of this system for the *Columbia* and *Minneapolis*. It was not possible, at the time of the design of these vessels, to obtain, in the United States, sufficiently large forgings for such great power as it was desired to install if the twin-screw system were adhered to. Other chief factors were the greater safety of the machinery and of the ship due to the use of three screws, as well as the then conjectured, but now proven, increased economy due to the use of triple screws.

To-day we have a somewhat different case presented in the design of high-powered cruisers or battleships. The conditions have changed. We are confronted no longer by the probable inability of the steel manufacturers to furnish forgings and castings of any size we may desire, for any power yet designed to be installed in a man-of-war. On the contrary, we have examples of engines of about the power we desire to use for our fastest vessels already constructed in the United States, and giving complete satisfaction, not only to the designers, but also to the builders and to the owners. The science of metallurgy

has made such progress in the last decade that we are now able to specify, regularly, steel of 95,000 pounds tensile strength, 21 per cent. elongation in 2 inches, and to stand cold bending to an inner diameter of 1 inch without showing cracks or flaws. Improved methods of forging, our more thorough knowledge of fluxes, the exclusive use of nickel-steel for high-grade engine construction, the judicious employment of annealing and tempering—all these, combined, enable us to secure stonger materials, and now we obtain a vast increase of power without a much greater weight than that required ten years ago for the lower powers then prevailing. The reduction in weights is most apparent in the moving parts. This is an important point, as it has meant that the growth in power has not been accompanied by an increase in vibration, a matter that is likely to limit speeds of rotation in the future.

We are no longer forced to divide the power among three shafts because of the impossibility of obtaining one sufficiently large to transmit half the power. We can now secure in the home market all of the materials needed for the machinery of the highest power yet planned.

There are many other considerations, however, both tactical and engineering, which make it still advisable, at least for the highest powers, to use the triple-screw method of propulsion for our men-of-war.

The most evident advantage from the use of three screws is the consequent subdivision of the power. This is of particular moment on war vessels, where the possibility of disaster in battle is to be considered, as well as that of accident in time of peace. Not only does the increased number of engines decrease the probable amount of power that may be disabled at any time, but also the chance of fatal injury to the ship, through its motive machinery, is lessened greatly. The danger from a shell is decreased. It would require three shots penetrating the steel deck to completely disable a triple-screw ship, as against but two in the case of a vessel fitted with twin engines. This, however, is assuming a possibility which may not be a fact, that a shell will not have any disastrous effect outside of the compartment in

which it explodes. It is probable that the vertical bulkhead between the engine rooms cannot be so entirely depended upon as to restrict the effects of an explosion. It is quite possible that a single very lucky shot might disable completely a twin-screw war vessel. If so, then it would surely take at least two such shots to inflict corresponding injury on any ship with triple screws. In case of the wrecking of any single engine the amount of power lost with twin screws would be one-half, as against the much less reduction of one-third in triple-screw ships.

It may be urged, and with justice, that the engines of our men-of-war are already well guarded from shell fire. If it can be shown, however, that the protection can be increased without consequent loss in other directions, it will surely be well worth while to adopt the system affording greater security. In the old days of sailing ships many a battle was won, sometimes against superior force, by the disablement of the sail power of one of the combatants. After the motive force of any fighting ship was gone, she was at the mercy of her foe. In our time, when battleships have a fair all-round fire, the likelihood of this is somewhat reduced; but it is still apparent that any ship which is inert on the sea is far the inferior of her dirigeable enemy. Any system which increases the chance of securing and keeping the "weather-gage" in battle, must be good.

Should one of the propelling engines be disabled, there is not nearly as much interference with what is called the handiness, the steering qualities of the ship, if there are three screws, as if there be but two. With twin screws and one only is use, it is necessary, in order to keep the vessel on her course, to use a helm angle of from 6½ to 10 degrees. This is the amount when the screw of the idle engine is left to revolve freely. We have attempted to get over this difficulty by using diverging shafts, and thus reducing the turning effect of the engines; but this is objected to by the deck officers who wish for vessels which can readily "turn on their heels." Of course, the less the fraction of the power that is disabled, the less the ill effect on handiness.

For war vessels it is desirable to make the water-tight compartments as small as possible. The reduction in the smaller

sizes of engines in three-screwed ships leads to this end; and, as will be pointed out later, this is effected with no increase in the total engine-room space.

One of the greatest advantages from the use of triple screws is that smaller propellers are required for the same total power. This particular in itself presents sufficient advantages to justify the use of three engines on warships—advantages which are so practical, engineering and tactical, that it is surprising that this point has not been more thoroughly developed.

A very large part of the loss of power at the propeller is due to the frictional resistance of the water to the passage of the propeller blade. This resistance increases with any increase of the peripheral speed of the blades, and low speed will be advantageous in this regard. It is assumed, of course, that due account is taken of the ratio between the pitch and diameter of the screw. If this ratio be not unreasonably increased, however—and with the large hubs used in current designs, this ratio may be profitably rather high—it will be a great gain from an economical standpoint to reduce the peripheral speed. With very high speeds and powers this speed is now very near the critical point beyond which the friction is excessive, and the effects of cavitation begin to be felt. The decrease of pressure upon the forward sides of the screw blades, at high velocity, is not a negligible quantity. The matter of proper propeller design is too complicated to be more than glanced at here, but it must be evident that to reduce the peripheral speed would be advantageous in the cases of the screws of large diameter necessary in the application of very high powers.

Now, the use of three screws allows a reduction in diameter of screw of over 20 per cent., and while, as will be pointed out, this is accompanied by an increase in the number of revolutions, the speed of periphery may readily be reduced below what is required in twin-screw practice.

At the stern of the ship, amidships, in the following wake always present to some extent with the most carefully-designed hulls, the effects of a large screw are not so signally bad. I think that "cavitation," or the tendency thereto, is reduced

greatly in this following wake, and, on that account, I believe that a considerably greater efficiency is obtained from the screw at the stern post than from those on the quarters. Whatever the cause, this increase in efficiency is so well shown by the results of trials that it can no longer be questioned.

I mean, of course, the trials of large ships, not tank experiments. The latter serve very well for determining the actual resistance of a hull; but not for fixing the economy of propulsion, or the ratio between the towing and indicated powers. It is in the increase of efficiency, and not in any decrease in resistance, that the economical advantage of triple screws must be found.

No test of a propeller can be held to have so much value as a test upon ships. Model experiments of propellers are not satisfactory. It requires experiments, with the full-sized screw, working at the designed pitch and at its designed speed, under its full load of work, to give us conclusive results. Trials under these conditions show, as I have said at first, a considerable advantage due to the use of triple screws.

Investigation along this line has not yet proceeded far enough to enable me to give more than tentative figures as to the propulsive efficiency due to the different methods of arranging the screws. It is, however, certain that there are gains from both the use of small screws, and of a screw working in the following wake, and that these gains would naturally grow with an increase in speed. Speaking only of full power trials, it will probably be found that, up to some low speed not yet determined, it will be best, from the economical standpoint only, to use a single screw; beyond this point it will be found that the use of twin screws would tend to a reduction in the power required for a given hull and maximum speed, and that, at any time where twin screws are good triple screws are better. I estimate the average economy over single-screw ships from the use of twin screws, as about 8 per cent. for vessels of maximum speeds from 12 to 20 knots, and I consider that triple screws are more economical than twin screws by from 5 per cent. for 15-knot ships to 12 per cent. for those of 24 knots speed. These figures

are approximate; but they are from trial data of many ships fitted with the different methods of screw propulsion.

I have discussed this point at considerable length, principally to develop the following conclusions:

(1) The use of triple screws leads to a considerable economy at the highest speeds.

(2) Decrease in size of screws is peculiarly economical as regards the wing screws, and

(3) To evenly distribute the ill effects of high peripheral speed, and to take advantage of the following wake, the center screw should be made larger than the wing or side screws.

But there are many other advantages due to the smaller screws, particularly the smaller wing screws, and especially for men-of-war.

In ramming an enemy, if all goes well, there would be little difference between the twin and triple systems, but a glancing blow from either forward or aft would certainly take off the enemy's side screw if, as in twin practice, it projected beyond the counter; and, later on, as the ships rubbed past each other, one's own side screw would be broken, under the same condition of projection. But, with a small screw, such as can be had in the triple system, neither propeller would be damaged, and the stern screw would be safe in any event. This point is of value, too, in ordinary cruising, where a floating log or a pile in a river would disable a propeller of a twin screw ship, while the obstruction would have been pushed clear of the smaller propeller of a triple screw by the ship's hull. Going alongside dock also—that bugaboo to commanders of high-powered, fine-lined, speedy, twin-screw vessels—would be made much easier.

The shorter shafting required for getting the smaller propellers clear of the ship would allow these screws to be placed further forward, where they would be better protected by the hull. This shorter shafting would also decrease the strains on the propeller shafting in bad weather, and would often obviate the necessity of an extra supporting strut, giving, as well, a decreased danger of fracture and the possibility of decreasing the weight.

The fact that with smaller screws the tips of blades are lower

in the water than with the twin-screw system, gives advantages. The design of the upper and fuller stream lines could be considerably freer. If it is considered advisable (and I have no doubt the hull designers will show that this gain is not of great moment where a central screw is fitted), this advantage could be passed over in favor of giving the wing shafting a slight inclination upward, so as to obtain a horizontal thrust when the stern of the vessel settles in the water at full speed. Ordinarily, however, the squatting of the ship would be insignificant. The fact must not be overlooked that the lower the propellers are placed the freer the access of water, and the more perfect the action of the screw.

With tips of blades well buried, the danger of racing is decreased, each extra foot of immersion reducing it. Anyone who has stood by the throttle, checking the engine with the heave of the ship, appreciates fully this advantage. The central screw, of course, would never race except in a sea where the ship was pitching heavily; while the side screws, being well forward and deep in the water, would probably never give trouble in the worst of seas.

When the use of three screws was first proposed, the idea prevailed in the minds of most engineers that the "race" of the water from the side screws would materially affect the action of the central screw. The error of this supposition was fully shown by the trials of the *Columbia* and *Minneapolis*. In the *Columbia* the pitch of all screws was made the same. The trials of this ship having shown the revolutions of the central screw to be less than those of the wing screws, the pitch of the central screw on the *Minneapolis* was made six inches less than that of the side screws. On the trials of the latter vessel the speed of rotation of the central screw was almost precisely a mean between the speeds of the two side screws, which differed slightly in pitch. This result was obtained without any "jockeying" of the throttle or change in the cut-off.

Attention has been called to the feasibility in the triple system of securing a greater number of revolutions, owing to the reduction in diameter of the propeller giving decreased friction of the

blades. This matter of increased speed of rotation affects directly the efficiency of the machinery, especially in warships, where the stroke of the engine is limited by the height below the protective deck. The piston speed must be high to get the required power from modern machinery without too cumbrous low-pressure cylinders. Any increase in piston speed, or in the number of revolutions, decreases the condensation in the cylinders, as the item of time is one of considerable importance as far as this condensation is concerned. And, further, as a consequence of greater piston speed, we obtain lighter engines and shafting. For small powers, it is generally possible to obtain great piston speed in our low naval engines, by a great number of revolutions; but there has been pointed out the difficulty of obtaining efficient propellers at high rotative speeds, for transmitting great powers. We know, of course, that it is possible to get an efficient propeller for the very highest powers yet used; but these propellers must be of great diameter in large ships, and in the United States we look into the matter of draught very closely. Our vessels are built for entering comparatively shallow harbors, and it is not easy to secure a screw that will be efficient, and that will fit on a 22-knot, 12,000-ton ship of no more than 24 feet draught. There must be a certain minimum immersion of the screw blades, and this must be greater for twin-screw than for single-screw vessels, because of the rolling of the ship. It is necessary, also, to have a considerable difference in level between the keel and the lowest part of the screws in a twin-screw vessel. It will surely be difficult, and, I believe, impossible, without the use of high glacis plates, to obtain satisfactory machinery for twin-screw ships under the conditions named, 22 knots, 12,000 tons and 24 feet draught.

In the design of marine machinery, it is important that the ratio between the stroke and the diameter of cylinders be kept sufficiently high. This ratio is necessarily low in all naval vessels, as compared with the merchant service, on account of the necessity of keeping the machinery below the protective deck. Of course, the larger the power and size of the low-pressure cylinder, the longer the stroke should be, and therefore the

greater the height of engine room required for a properly-designed engine. The greater the draught, the greater the possible height of engine room, and, for the same number of revolutions, the greater the piston speed. It is unquestionable that, where more than, say, 10,000 horsepower is to be transmitted through a single shaft, under present conditions of speed and displacement, the number of revolutions will be limited by the propeller. We, in the United States Navy, having ships of very light draught, as compared with other fleets, are most hampered in this regard.

It has been shown that the use of triple screws would tend to a decrease in the volume of the cylinders required for giving the powers. This is quite apart from the fact that the power is divided into three parts instead of two, and is due to the greater piston speed possible with the smaller screws. It will be seen, then, that considerably more latitude is allowable in the design of machinery for ships with triple screws than would be possible if twin screws were used. If three engines are installed, it is certain that a less height is required under the protective deck than would be necessary for a twin-screw ship.

It is to be noted, then, that the economy of a triple-screw ship is developed not only in more efficient propulsion, but also in the more efficient use of the steam in the engines due to the decreased condensation following the increased number of revolutions and the greater piston speed. The economy of propulsion is thus increased as a result of both increased propulsion efficiency, and of increased efficiency of the engines. A decreased total weight of the machinery is also a natural result of the use of triple screws.

It is, of course, a fact that the use of three engines multiplies the number of engine parts. The resulting disadvantage is, however, much more apparent than real. The *Columbia* and *Minneapolis* are examples of the practicability of installing large power in three three-cylinder engines, and this was accomplished with a stroke of but 42 inches. There is no doubt that it would have been necessary to use four-cylinder engines, at least, if twin screws had been used. The absolutely necessary increase

in the number of cylinders is thus shown to be but one-eighth. Of course, it is understood that the use of three-cylinder engines is now generally approved. It is merely pointed out as feasible, and as intended to show that the arguments against triple screws, based on the multiplicity of engine parts, could readily be made of practically no weight, if other conditions did not render advisable an increase in the number of cylinders.

Water-tube boilers have now come to stay, at least as far as the United States Navy is concerned. These bring with them steam of high pressure, and cause the use of quadruple-expansion engines for economy's sake. At 200 pounds pressure the quadruple-expansion engine gives sufficient gain to justify its employment. Owing to the low powers of peace cruising with men-of-war, it is questionable whether it is desirable, with these ships, to design engines for the greatest economy at the highest powers. Unquestionably an arrangement of cylinders which gives the greatest economy at the highest powers produces a markedly uneconomical engine for the lower powers ordinarily used in peace.

The wide variations in present designs show how different designers view this problem. It is extremely complicated, and I am free to confess that much more data than are now available are needed for a full solution. We must know the cost of running the auxiliary machinery, and not only the average power of the main engines, but their range of power must also be carefully considered. It has been thought advisable, however, in the design we are proposing for our latest fast ships, to use quadruple-expansion engines throughout, using thirteen cylinders, in all, in the three main engines. This is a considerable change from the practice of twenty-five years ago, when two cylinders were most frequent. But the fact that this large number of cylinders has been adopted shows that our experience, at least, is that the argument of the multiplicity of parts of the engines has comparatively little weight. The decrease in the size of parts, with the consequent increase in accessibility, in accuracy of adjustment, and in case of repairs, is a natural sequence of the growth in the number of parts, and seems sufficient to

overcome the disadvantages. It will be pointed out, further, that the increase in the number of working parts due to the use of triple screws is only apparent, as, ordinarily, there would be not more than eight cylinders employed on our triple-screw ships against ten cylinders that would necessarily be used in the proposed five-cylinder quadruple-expansion engines for our twin-screw ships.

A much more serious objection to the use of triple screws than the multiplicity of engine parts is found in the greater intricacy of the piping plans, and in the increased number of valves required. This objection is serious. Our twin-screw warships are complicated enough at best. This disadvantage has been reduced somewhat, however, by several simple methods. The use of electrically-operated auxiliaries has done much in this respect, especially as regards piping outside of the machinery space. Our piping plans are very carefully studied, and are so designed and arranged as to reduce the number of valves to a minimum, and to render plain to the engineer the leads of all pipes. All valves are marked mainly to show the connections. Many of them indicate, as well, the amount of opening of the valve. As a result of this care in the laying out and installation of piping and valves, mistakes in the operation of the valves are made almost impossible, and undue intricacy of the piping plans is avoided. This absence of complexity is especially marked when comparison is made with some of our earlier twin-screw ships.

The growth in number of auxiliary engines, owing to the employment of three main engines, is another disadvantage of the triple-screw system that is much more apparent than real. Ordinarily there is no increase in the number of auxiliaries in use, only an increase in the number available for use; and, as a rule, these uneconomical auxiliaries are worked much more nearly at their rated capacity, and are thus considerably less wasteful of steam. Our experience has been that the auxiliary machinery gives most of the trouble on board ship, and our vessels have been more frequently disabled on the account of the failure of these small engines than from any other cause due

to the machinery. A larger reserve power in this, the weak part of the machinery, is too great an advantage not to be well worth its cost.

The increase in engine-room force required with the three engines is not excessive, being twelve men at the most. This cannot be considered a disadvantage for warships. The added staff consists entirely of skilled mechanics, and these men are especially useful in making repairs while under way. Our recent war experience tends to show the imperative necessity of some such mobile reserve for the maintenance of a vessel, constantly under way, in a condition, at all times, of thorough efficiency. With this increase, there is always some one at hand to take the place of any man overcome by heat or sickness, and crippling of the crew, as well as of the machinery, is guarded against. I repeat that the increase in the engine-room force necessitated by the adoption of three propelling engines cannot be counted a disadvantage in men-of-war, under war conditions.

The formation of the stern post and rudder is made somewhat complicated by the use of the central propeller, but not more so than in any single-screw merchantmen, and I apprehend that this disadvantage will not be given great weight to by any designer.

To obtain a proper conception of the advantages of triple-screw propulsion it is necessary to consider also the latitude afforded by this system in the methods of running the ship under cruising conditions, since either one, two or three screws may be used. There have been many trials of triple-screw ships under each of these methods of propulsion, and it may be interesting to give a few of the results, which have not hitherto been published, so far as I am aware. Taking a vessel of, say, 12,000 tons, 23,000 H.P. and 22 knots speed, when all engines are used at full power, it is found that—

(1) The power to drag one screw, uncoupled from the engine and left to revolve freely, is 150 H.P. at 10 knots; 600 H.P. at 15 knots.

(2) If coupled to the engine, at 10 knots speed the power absorbed in dragging is slightly in excess of 300 H.P.

(3) If two screws are dragged, the loss from drag is practically

double what it would be with one idle screw for the same speed of the ship.

(4) The loss in power due to condensation in an engine (not the result of expansion of steam in the cylinders, but attributable directly to the heating of the cylinder walls) is almost exactly one pound of steam for each horsepower of the maximum power for each engine. This figure is approximately correct for all speeds, increasing slightly for the lowest speeds. It applies to jacketed engines.

(5) With three equal screws, the center propeller has not sufficient area to give economical results when used alone at speeds above eight knots. With three equal screws, the use of the two wing propellers alone can be depended upon to give a considerable gain in economy for all speeds from 8 to 17 knots inclusive. These results have been gathered from fully authenticated trials, not only of our own ships, but also of triple-screw ships in other navies.

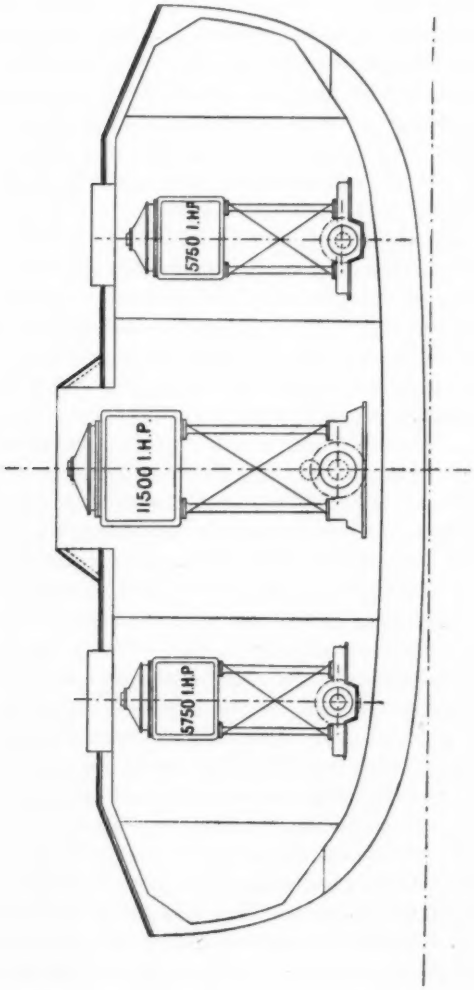
All screws are practically equal in disc area in the trials from which these results are obtained.

With these points known, the problem of the design of triple-screw ships is greatly simplified. The disadvantage of the drag of a screw is measured, and the advantage of the fitting hitherto adopted, which provided for the disconnecting of any idle screw from its engine, is clearly developed. The necessity of giving sufficient disc area of propeller is, as was to be expected, prominently shown by the failure to secure economy with one engine in use, except at the very lowest speeds.

The value of economical engines is so universally recognized to-day that it seems almost unnecessary to mention it; but this value is, in a warship, far greater than the mere saving in the coal bill, though that is an important item. The matter of economy in the use of coal may make all the difference between victory and defeat. Coal endurance limits the radius of action of the ship, and determines definitely the scope of her operations. Of course we can—as we did recently in two cases—assist a monitor across the Pacific Ocean in case of need, but that tardy reinforcement might have been too late. Economy at the engines

increases the speed of these reinforcing ships where that economy can be gained without a reduction of bunker space; it increases the potential value of each pound of coal, and 10 per cent. may often make the difference between success and failure. If this economy were measured alone, and not from the military point of view, it might be proper to consider the question whether three engines have a greater first cost than two of the same total power, but economy means more than that. It means victory, and it is for this that men-of-war are built.

If three screws are to be fitted to a warship, and the design is to conform to the conditions of economical propulsion obtaining on these vessels, as shown by our present knowledge of the effects of three screws upon propulsive and engine efficiency, there appear to be but two practicable arrangements. The central engine should be considerably more powerful than either of the wing engines, or it should be considerably less powerful. This follows from the fact that a propeller design which will give in one screw sufficient area for the ordinary cruising speeds up to 12 knots, is nearly impossible if the same screw is designed to be worked as one-third of the propelling system for the highest speed of the ship. The proportions of the screw must be changed to suit the latter conditions. It is evidently not wise, also, to use as much as two-thirds of the full engine power for cruising at one-tenth power. The use of three equal engines is, therefore, out of the question, as far as comparative economy goes. If a small center engine be used, it would be practically an auxiliary. A very large screw necessarily being fitted to secure a fair propeller efficiency at low speeds, when the small engine alone would be used, it would be of practically no value at the highest speeds. I consider, therefore, that it would be far better practice to use a large center and two small wing engines, in which design under no conditions would there be a useless engine. Of course, either of these plans, involving the use of two different sizes of engines on the same ship, is disadvantageous; but this disadvantage is not so great as a casual view of the conditions would seem to indicate. Engines do not break down in service. Careful designs for the maximum power insure good working of the machinery. Accidents to the en-


5750 I.H.P
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5750 I.H.P

gines are extremely rare, and are due, almost invariably, to some defect in a seemingly unimportant detail. The engine itself, so far as its large parts are concerned, does not break down, and a supply of the lighter spare parts provides for all emergencies, such as are ordinarily met. On the other hand, it is well to note the many advantages due to the use of different engines. There is, in particular, much to be said in favor of the plan of installing small wing engines in a triple-screw ship. It is a fact that commanders of our ships hesitate, as naturally they should, to enter or leave a port with only one screw in use. They desire to retain the practical advantages of handiness accompanying the use of twin screws. It is, further, a fact that ships which ordinarily cruise at speeds of from 14 to 16 knots we have found to make better speeds in time of war than ships of the same class, but of lower cruising speed. These conditions, combined with the proved efficiency of the use of the wing engines at speeds up to 17 or 18 knots, have been with us the determining factors in causing the adoption of designs involving the use of the smaller wing engines. It has been found advisable to fit economical machinery for cruising at speeds as high as 16 knots. While engines which will be most economical at this speed will not be the most desirable in this respect for a speed of 10 knots, they will retain considerable advantage over any other system in the reserve which will be ready for instant use.

The problem of the design of the propellers to give a proper efficiency for low speeds, and to be good also at the highest speed, offers in this system no difficulties. The reduction in the size of the wing engines, below what would be necessary if three equal engines were used, effects a saving of about 200 H.P., or its equivalent in steam due to the decreased condensation on account of the smaller engines. This figure applies exactly to our recently-designed 22-knot armored cruisers. The ship is economical at all the ordinary cruising speeds from 10 to 17 knots. The tactical advantages of working with twin screws are retained at all speeds, high or low. It has been pointed out that the decrease in size of screw is especially advantageous for the wing screws, and that it is advantageous, on account of the superior propulsive efficiency of the screw working in the follow-

ing wake, to have a large power on the center engine. These conditions are especially well fulfilled by the use of the smaller wing engines.

To reduce the engine-room space it is advisable to place engines abreast in the ship. It is also a great advantage to arrange the engines in this way, as it makes possible the placing of a part of the boiler power abaft the engine, which gives easy solution to all problems connected with the change in trim due to the use of light water-tube boilers, and also reduces vibration by placing the engines in the strongest part of the ship. In fact, the center and most powerful engine is exactly at the point of greatest resistance of the hull to vibration. By using smaller wing engines it is also easier to arrange the engines abreast than it would be to install twin-screw engines of the same total power. This follows from the lozenge shape of the space available for the engine rooms beneath the sloping protective deck and above the rising bottom of the ship. Again, but one screw is dragged with the two engines in use. This screw is a large one, it is true, but the drag is probably not so great as it would be with two smaller screws of the same total power.

It is also regarded as an advantage for this system that there is always one-half the full power available in case of accident.

The center engine is seldom used, and our experience goes to show that it is always in a condition of very good efficiency. The customary employment of the smaller wing engines insures ease of making the regular repairs. It is but fair that I should state that, with its very large screw, designed for transmitting about half the total power at full speed, the use of the center engine alone may prove slightly more economical than that of the wing screws for a speed of about 10 knots, this superior efficiency following from the working of the screw in the following wake. I do not expect, however, that the center engine will often be alone employed, as the maneuvering qualities and general handiness of the ship are so much improved by the use of two screws at all times. It should, however, be pointed out that the handiness will be retained at full power, and will not be affected badly by the reduction in the size of the wing engines.

In a word, the arrangement of triple-screw engines, with approximately one-half the total power placed upon the center engine, and approximately one-quarter on each of the wing engines, seems to fit a warship and its conditions remarkably well.

Ramming and torpedoing would lose much of their danger with the small engines outboard. There is a certain prejudice among naval officers against any system that shows so plainly as do triple screws the enormous amount of power installed in the ship and so seldom employed. These officers would possibly prefer to imagine all the power in use, even when knowing, as they all certainly do know, that frequently not 10 per cent. of the total power is actually being developed. The loss from drag of an idle screw is plainly seen, but they forget the loss in the engine cylinders from condensation, which is often much greater. Not to employ ordinarily the reserve-power plant increases the value of this reserve as well as the economy. It may appear unwise to install a plant that is so seldom used, yet when the power is wanted it is wanted badly, and at such times every pound of coal in the bunkers may be worth a ton at ordinary times.

The use of two screws with two engines upon each shaft has not been considered as an alternative to the use of triple screws. This arrangement, with its four engines, has nearly all of the disadvantages attendant upon the use of three screws, with very few of their advantages. Further, it presents the grave tactical disadvantage which was developed so fully in the cases of the *Brooklyn* and *New York* at Santiago. These vessels were fitted with four engines working twin screws, the forward engines being ordinarily uncoupled. This system was designed to insure economical running at low speeds; but it was impossible to couple up the forward engines without stopping the ship. During the battle of Santiago, stopping the ship for the fifteen minutes necessary to couple up the engines would have been fatal. On the contrary, in the case of the *Minneapolis* the center screw was coupled up while the two wing screws were driving the vessel at a speed of 17 knots. This was done when the

ships of Admiral Schley were sighted off Santiago, and before the identity of his fleet was established. It is a great advantage that full power can always be applied on a triple-screw ship without stopping. Such conditions would surely have been very valuable to the *New York* at Santiago.

It may naturally be inquired why the superior efficiency due to the use of triple screws has not led to their general adoption in the merchant marine. Triple screws undoubtedly would have been used in that service if the conditions obtaining were the same as those existing in the Navy. Merchant vessels, however, instead of running at a variable speed, are always worked at their full power, and there would be, consequently, no advantage to their owners in fitting machinery capable of working economically at low speeds. The stroke of engines in these vessels is also not limited by a protective deck, and it is always possible with them to obtain the great piston speed necessary for economy by increasing the height of the engine. We see, therefore, that two of the main reasons for the use of triple screws in men-of-war do not obtain in the merchant service. Added to this must be the fact, that the cost of building and installing three engines, when not all of the same size, is considerably greater than that of two engines of the same total power; and also, that the cost of maintenance due to the larger force required would be considerably increased. From these considerations it would appear that triple screws may not be desirable for the merchant service, under present conditions of size and speed. I think, however, that any transatlantic line which would definitely adopt the triple system, would be patronized by a considerable number of persons, because of the greater security afforded by its use.

The statements I have made as to the desirability of using three screws on war vessels, and the fact that they are being used to so great an extent in the Continental Navies, will naturally lead the thoughtful student to wonder why they have not been adopted, to some extent at least, in British vessels. This feeling will be the stronger from the fact that British engineers are justly considered to be thoroughly progressive, and abreast

of the times with respect to every feature that would tend to an increase in the efficiency of vessels.

It has occurred to me that, whatever other reasons may have caused this non-use, until now, of triple screws on British vessels, one feature of the case at least may serve as a partial explanation. I am led to this belief all the more from the fact that it agrees with the experience of all designers with respect to some forms of marine machinery which, while apparently very peculiar, are the best adapted to the particular cases where they have to be used, viz: the exceedingly light-draught steamers required for certain river service.

Yacht designers are very familiar with the fact that vessels designed for general cruising on the English coast are very different from those for general use on the coast of the United States, due to the fact that in England there is everywhere an ample depth of water, while in the United States the reverse is the case.

In just the same way, we in the United States are restricted in the draught of our war vessels to about 24 feet, while the large British ships can, and do, in some cases, draw about 27 feet. As a consequence of this radical difference in the circumstances under which large powers have to be applied, the problem of the number of propellers is presented to the designers on the two sides under a different aspect, and I am inclined to believe that this has had a great deal to do with the fact that British designers have not paid much attention to three screws thus far. Had they been compelled to face the problem of puting large powers in light-draught hulls, I think they would have been driven to a consideration of the advantages of three screws, and probably would have taken hold of the matter with their characteristic energy.

Let me add, in conclusion, that I have given this subject of triple screws very careful study, and I believe that for war vessels their use is thoroughly logical.

Further than that, I believe that, although contrary to the generally accepted idea of duplication of parts as far as possible, the plan which I have suggested for dividing the power between

one large central engine, to develop about half the power, and two smaller wing engines, each of about one-quarter power, will give the best results, and is likely to be the system that will finally obtain general adoption.

THE CASE OF TRIPLE SCREWS.

Their Advantages.	*Their Disadvantages.*
Smaller engine parts.	Greater number of parts.
Greater ease of overhauling.	Greater number of valves and pipes.
Greater accuracy of adjustment.	Greater number of auxiliaries.
Lack of vibration.	Increased engine-room force.
Subdivision of power.	
Increased (probable) available power.	Loss of power due to drag of idle screw.
Increased ease of protection.	With center engine alone used, the loss of tactical advantages due to twin screws.
Increased handiness when partly disabled.	
Smaller water-tight compartments.	
Smaller propellers.	
More efficient propellers.	
Less peripheral speed of propellers.	
Less screw friction.	
Increased revolutions of engines.	
Decreased loss from cavitation—the word being used in its broadest sense.	
Increased efficiency of the screw working in following wake.	
Decreased danger to propellers in ramming.	
Decreased danger to ship that is rammed or torpedoed.	
Shorter propeller shafting.	
Decreased racing of screws.	
Freer design of stream lines.	
Freer access of water to screws.	
Increased piston speed and economy.	
Decreased total size of cylinders.	
Decreased weight of machinery.	
Decreased condensation in engines at all—especially at low—powers.	
Adaptability to light draught.	
High ratio between stroke and diameter of cylinders.	
Less glacis plating required.	
Ease of propeller design.	
Latitude of engine design.	
Great gain in economy at low powers.	

THE CASE OF THE PROPOSED SYSTEM OF TRIPLE SCREWS WITH SMALL WING ENGINES.

Advantages.	*Disadvantages.*
IT FITS THE SHIP.	Two sizes of engines in same ship.
Ease of installation and design.	Increased cost of building.
Great gain in economy at all speeds.	Increased number of spare parts necessarily carried.
The tactical advantages of twin screws economically retained.	
Engine-room space is reduced.	
The powerful center engine has a most economical screw working in following wake.	
The vibration is minimized.	
The loss from drag of screw is minimized, one screw only being dragged.	
Small size of working parts.	
Two independent plants, each capable of economical propulsion up to fifteen knots speed.	
Small size of working parts, with maximum ease of repairs.	

The disadvantages are few, and, from a broad standpoint of military excellence, they are unimportant. The advantages are many, including better design and installation, greater ease of maintenance, and greater efficiency at all speeds. I consider this the logical arrangement of motive machinery on high-powered warships.

Discussion.

The following letter from **Mr. Magnus Sandison** (Member) was read by the Secretary at the commencement of the discussion:

Newcastle-on-Tyne, *March 22, 1899.*

The Secretary, Institution of Naval Architects.

Dear Sir: I am sorry I am unable to be present to-morrow at the discussion on Admiral Melville's able paper on the propulsion of vessels fitted with triple screws.

Admiral Melville gives some very interesting figures regarding the power required to drag uncoupled screws in the case of such vessels, and lays very great stress upon the necessity for economy in coal consumption when cruising.

He says: "If three screws are to be fitted to a warship, and the design is to conform to the conditions of economical propulsion obtaining on these vessels, as shown by our present knowledge of the effects of three screws upon propulsion and engine efficiency, there appear to be but two practicable arrangements. The central engine should be considerably more powerful than either of the wing engines, or it should be considerably less powerful."

Having in view the vast difference in the power required to propel a cruiser at eight or ten knots as compared with the power required to propel the same vessel at a speed of twenty-two or twenty-five knots, and the very poor performance of the twin engines at the lower speeds, I prepared a design of machinery about seven years ago which embodied the second of Admiral Melville's proposals.

My idea was that the vessel should be propelled at the lower or cruising speed by a small engine of only sufficient size to develop the requisite power, and so proportioned as to develop that power with an economy equal to that attained in the best examples of the Mercantile Marine, the shafts of the main or "wing" engines being uncoupled forward of the thrust blocks leaving the propellers free to revolve.

This "cruising engine" was to be of substantial design and adapted for continuous steaming at full power over long periods. It was to be accommodated aft of the main engines in a separate watertight compartment, or even placed at the aft end of the vessel in the same compartment as the steam-steering engines.

Steam was to be taken from an auxiliary steam-pipe system in one, or other, of the engine rooms, and the engine would either have its own condenser or one, or other, of the auxiliary condensers could be utilized. These condensers are, of course, only worked to their full capacity when the main engines are developing a large percentage of their maximum power, and the forced-draft fans and other auxiliaries are running at a proportionate speed.

The propeller of this engine, to reduce its resistance when the vessel was being propelled by the main engines, was intended

to be of the feathering type; or, of course, the engine could be run in conjunction with the main engines.

There is no doubt but that many advantages would accrue from the adoption of some such arrangement.

Yours truly,

MAGNUS SANDISON.

Mr. A. E. Seaton (Member of Council): My Lord and Gentlemen, no doubt this paper is a very interesting one, very ably prepared and written. We are very much indebted to Admiral Melville for giving it to us, and thereby adding another very good reason for regarding the Institution as of international interest. I think the Admiral, however, has rather stretched his case further than was necessary, and has adopted what I may almost call special pleading in many cases, which will scarcely bear very close investigation. No doubt he has made out the very best case possible for three screws, and, in doing so, has magnified to the very utmost the advantages of the system, and minimized to the very utmost the disadvantages. He says he is a little at a loss to understand why the triple screw has not been adopted in the British Navy, and he almost hints that it is in part due to our conservatism. Perhaps that is so; but, it may be interesting to him to know, and to you, gentlemen, also to know, that three screws were tried in the British Navy some forty odd years ago. It is true the trial was an accidental one, but nevertheless it was an interesting one, inasmuch as it was resorted to for the very reason that the Admiral urges as one of the best for the adoption of the triple screw. Some of our older members may know better than myself—I only know the circumstances by hearsay, but I believe it arose in this way. During the Russian war one of the floating batteries* built, developed such a very poor speed that some-

* H.M.S. *Meteor*, 1,469 tons, 172 feet 6 inches by 43 feet 11 inches; draught of water, 6 feet 5 inches forward, 8 feet aft. When tried with a single screw, 6 feet diameter and 12 feet 6 inches pitch, the speed was 5.77 knots; the revolutions being 139, the I.H.P. 530, slip per cent., 66.3. With two screws added, each 6 feet diameter and 7 feet 6 inches pitch, the speed was 5.23; the revolutions 113, the I.H.P. 498, slip per cent. of center screw, 62.46, wing, 37.4.

thing had to be done. She had, of course, a single screw. The authorities at that time came to the conclusion that it was due to the smallness of the screw, and as her draught of water did not permit of a larger screw some other means of increasing the speed had to be adopted. It was then suggested to fit two wing screws, driven by gearing from the main engine; in this way we had, for the first time in the Navy, a three-screw ship. I understand the result was not satisfactory, because I have no doubt that any improvement that might have been got by the three screws was prevented by the excessive friction of the wing gearing. Admiral Melville speaks of the economy due to the three screws, and says, "I consider that triple screws are more economical than twin screws by from 5 per cent. for 15 knot ships to 12 per cent. for those of 24 knots." He does not say how he arrives at that, and they seem to be rather big figures. The economy, of course I take it to be in horse-power or coal consumption, but when we come to the economy of cost, he deals very lightly with it, and does not mention any percentage. In spite of what he says as to the usefulness of the increased engine-room staff, I scarcely think that is a good reason for three screws, inasmuch as in a twin-screw ship, if the advantages of the staff are as he suggests, and no doubt some of them are perfectly true, you could get them. The advantages he speaks of certainly would not exist in war time, when a ship is liable at any time to be called upon to go at full speed, and if any of the crew were sick or ill there would be no surplus staff, and the chance of repairing would disappear altogether.

I do not agree with the Admiral that there is any advantage in triple screws for ramming purposes. I think myself, when it comes to ramming, whether the screw is a foot more or less below the water, or a foot more or less inboard, if the ram approached the counter of the ship the outer screw of the triple-screw ship would be equally liable to damage as an ordinary twin-screw ship. I do not agree with what the Admiral says as to racing in rolling. It is not our experience that engines do race in rolling; in fact, most ships roll *with* the waves, and not *to* them, and consequently the screws do not come out of the water in the way we imagine.

Nearly all racing in twin-screw ships is due to pitching. We also think, with good reason, that the twin-screw ship does not race to anythng like the extent that the single-screw ship does; therefore, for the same reason that the single-screw ship races, the center screw of the triple-screw would race considerably.

The Admiral deals also somewhat lightly with a subject that came very greatly to the front some thirty or forty years ago, when sailing ships with auxiliary engines were fashionable. I think Dr. Scoresby points out more than once in his Diary what a nuisance the engines were in the *Royal Charter*. He went, as you know, on a voyage to Australia, to observe the effect of the magnetism on iron ships. This ship had a small engine capable of driving the ship at seven knots. The engine used to be started in calm weather, or when the winds were light, but if a breeze sprang up, and the ship began to gather way owing to her sails, and the speed went up to nine or ten knots, the engines raced so badly as to shake the ship dreadfully. Then the old question came up, which the Admiral has also dealt with, of coupling up and uncoupling, which was found to be no easy matter. For these reasons the engines in the *Royal Charter* were never used to the extent intended.

I do not quite follow the paper on pages 3 and 9 as to the numbers of the cylinders. In the paragraph at the bottom of page 3 the author says, "using thirteen cylinders, in all, in the three main engines." I can only suppose that he means that the wing engines are to be four-cylinder quadruples, and the center engines five-cylinder quadruples. Again, I am a bit puzzled as to the number of cylinders on the top of page 9. He says: "It will be pointed out, further, that the increase in the number of working parts, due to the use of triple screws, is only apparent, as, ordinarily, there would be not more than eight cylinders, employed on our triple-screw ships against ten cylinders that would necessarily be used in the proposed five-cylinder quadruple-expansion engines of the twin-screw ships." That is probably a misprint, and it may be capable of explanation.

In dealing with the capacity for repairs, due to increased engine-room staff, he has not laid great stress upon, or called

special attention to the fact that there would be more engines requiring repair—three engines as against two, and he has not spoken very much about the auxiliary engines and fittings that would be increased by the three engines.

What he says about auxiliary machinery is interesting. It appears in the American Navy more trouble has been caused by that than by almost anything else, and it leads one to consider the subject as one of primary importance, and to ask oneself whether the time has not come when the distribution of power on a warship should not be arranged pretty much on the same plan as we find on shore to be the best, namely, by using electrical motors. We have in them a very simple instrument, which is not very apt to go wrong, which is much more economic than the ordinary auxiliary steam engine on board ship, and whose power is generated by two or three highly efficient engines as against the power generated by twenty or thirty highly inefficient engines. I think that most of the auxiliary work on board ship might be done in that way. I am aware that there are those who claim advantages for the distribution of power by hydraulic pressure; but, on the whole, I think for a warship it is safer to use electricity. If three engines are to be fitted in a ship—and it must not be supposed in the remarks I am making I am altogether throwing cold water on the three-engine type of ship, I trust I am only criticising it in an impartial and fair way—but, if three engines have to be fitted to the ship I think there is no question but that the center engine must have considerably more power than the wing engines. The Admiral has not mentioned it, but no doubt an advantage would accrue if the center propeller were made two-bladed; because, when not in use it could be very much shielded by the body of the ship, and the drag would be very much lessened.

I do not, think, my Lord, I have anything further to say, except that this is a most important paper on a highly important subject, and I have no doubt that the debate which will take place to-day will put the pros and cons so as to permit us to view the matter as none of us have hitherto seen it.

Professor J. H. Biles (Member of Council): My Lord and Gentlemen, I am sure that you will all be pleased to have heard this paper from so eminent an engineering authority as Admiral Melville. It may not, perhaps, be very well known to some of the members of this Institution that before Admiral Melville was eminent as an engineer he was eminent as an Arctic explorer, and those who have read his charming book on "Through the Lena Delta" must be familiar with the fact that the energy he displayed in carrying that expedition through, or the remnants of it back to civilization, has been of value to him and to his country in carrying out the reconstruction of the United States Navy. In 1891, I had the honor of reading a paper on some recent American warship designs. At that time the ships which are referred to here by the Admiral were on paper, and just about commenced in construction. They were familiarly called in the American office the pirate—the design was called the pirate—the intention being that these ships were to be made so fast that no warship could catch them, and that they should prey upon the commerce of an enemy. They have been promoted since then from the rank of pirate to that of cruiser, and in the work that they did in the recent war they gave some very good and economical results.

Now, this paper of Admiral Melville is, as Mr. Seaton has said, open to some amount of criticism from the point of view that he tries to prove a little too much; that is on account of his enthusiastic nature; but it does not detract, I think, from the real advantages of triple-screw ships in certain cases. It seems to me, after reading his paper and knowing that that paper has been written after the whole question of the new designs for three-screw armored ships had been fully considered by the Navy Department at Washington, that the summary of it amounts practically to this: that as an alternative to a twin-screw ship, he takes a three-screw ship, into which he puts one of the two twin-screw engines divided into equal parts. Now, in some of the twin-screw ships there were four engines, such as the *New York*, the *Brooklyn*, and the *Blake* and *Blenheim*. If we depart from this point of view we see that he has taken one of those

sets and put each of the separate engines to the side screws and turned the other two sets into one set and put it at the middle line. In comparing the efficiency of the three-screw with the two-screw, one advantage that is due to the change of size of engine, say only half, applies only to one-half of the machinery in this type that experience has shown to be desirable in the triple screw. So that, what Admiral Melville commenced by saying, that there was a great advantage due to reduced sizes of the engine, can only half apply to the case they have evolved by their experience. The other dominating consideration certainly seems to be the question of draught. If you have a limited amount of draught, it is easier to have propellers with three engines than it is with two. But, of course, in addition to the possibility of getting in three screws on given draught there is the advantage that if you do adopt three screws, which are smaller with engines of equal power, even in a ship where draught is not absolutely limited, you get a better performance at sea in bad weather.

There is, unfortunately, in this paper no distinct positive statement as to facts upon which the improved efficiencies are based. The facts have already been given in a paper which Admiral Melville read before the Society of Naval Architects and Marine Engineers in the United States, or the facts that he had at his disposal; but his determination in that paper, so far as I remember it, of the propulsive efficiency of the triple screw—and, of course, it is really the pith of the whole of his argument that the triple screw is more efficient as a propulsive instrument—the method he used for determining this propulsive efficiency was to assume a certain net resistance to the hull. Now, those who are familiar with model experiments and the results of them will not, I think, be quite prepared to accept an estimate of the resistance of a hull which has not been tried in a tank; or, if some form very closely approximating to it has not been tried, and, therefore, so far as the two vessels referred to by Admiral Melville are concerned, I doubt very much whether the assurance he gives is quite as satisfactory as it ought to be—that the propulsive efficiency is so much higher. If we judge

of propulsive efficiency by the general method that is adopted by those who have not tank experiments available—that is the Admiralty constant of performance—then I do not think there is anything very remarkable about the performances of the *Columbia* and *Minneapolis*.

The statement that Admiral Melville makes, that a twin-screw ship is more efficient than a single-screw ship, and has a higher propulsive efficiency, seems to me to detract somewhat from the efficiency of the triple screw. Within my experience the best results of propulsive efficiency that I know of are certainly on single-screw ships, and I was rather under the impression that the advantage of the triple screw in propulsive efficiency lay in the fact that the center screw obtained the higher efficiency which is sometimes obtained in a single screw over a twin screw. Admiral Melville lays some stress on that when he says the center screw picks up the frictional wake of the ship and gets some power back on that account.

The statement on page 7, that "it is unquestionable that when more than, say, 10,000 H.P. is to be transmitted through a single shaft under present conditions of speed and displacement the number of revolutions will be limited by the propeller." That statement seems to me to want some qualification. Surely it is easy to reduce the diameter of a propeller and increase the number of revolutions, and the statement that the number of revolutions will be limited by the propeller, I think, wants some qualification.

Mr. Seaton has pointed out that, on page 9, what is claimed as an advantage for having a larger engine-room force is not a real advantage, because there is more work for the men to do. The statement with reference to Transatlantic ships, that three screws afford a greater security than two screws, I think really cannot have very much weight. The difference between one and two screws if you have a breakdown is the difference between having one engine and no engine, but the difference between two and three screws if you have a breakdown is the difference between having one engine and two engines, which

is comparatively of small importance in such unusual circumstances as the complete breakdown of one engine.

Sir William White, K.C.B., LL.D., Sc.D., F.R.S. (Vice-President): Lord Hopetoun and Gentlemen, I should have preferred to have intervened in this discussion later, because I am quite sure that my voice is heard here too often, but this is a subject in which I take, and have taken for the last twenty years, the keenest interest, and on which, I think, we shall be all glad if we can obtain more definite information. It will be remembered by members of this Institution that, about twenty-one years ago, I read a paper here in which I strongly recommended the use of twin screws in deep-draught ships. At that time that was not a popular view, and in some of the engineering publications at that time I did not have a very appreciative reception; but events have justified the view that, as speeds increased on a limited draught, twin screws would come in. And they have gone further than that, as I always thought they would; twin screws have come in as desirable features in propulsion where there has been no question of limited draught, for example, in the great cargo carriers of comparatively moderate power. I simply recall that circumstance, not in any spirit of self-glorification, but to indicate that, so far as possible, I keep an open mind on all these subjects.

I trust I have no prejudice except the prejudice of trying to find out what, under a given set of circumstances, is the best. I have had some difficulty in dealing with this paper, for two reasons; one is, that it contains a great many contentions, not a few speculations, some arguments, and very few facts. Now, in this matter, facts are what we want. My paper of 1878 was nothing but a summary and an attempted analysis of facts. When I heard that Admiral Melville, whom we all admire and respect, and who is one of our Honorary Members, was about to contribute a paper to our Transactions, I was delighted, because I said to myself, at last we are going to have the facts about triple-screw ships. Now I ask anyone to read this paper, and say if that is so. The two triple-screw ships—I believe

there are two in the United States Navy; there may be more, but I have not heard of them—have now been some years in service. They have been available for experiments. It is quite possible that experiments have been made, but we have not any results of those experiments here, therefore we cannot discuss the question on the basis of recorded experimental performances. Now, in the analysis of steamship efficiency we want more than is indicated here.

Admiral Melville says that in the preparation of a set of tables showing the power required to drive a vessel of a given displacement at a given speed, data have been used which were gathered from the results of about two hundred trials of nearly as many ships. It would be interesting to know how many of those were triple-screw ships. It is certain, of course, there can be only two out of two hundred where the author has the facts from his own experience. I think I have a fairly complete acquaintance with the trials of the triple-screw ships which have been so far built. If they were all put together it would be found that they made up a very small proportion of the two hundred. I regret that Admiral Melville is not here to tell me whether that is the truth, and whether it is not a fair deduction to say that such broad conclusions as are drawn on page 5 of this paper, as to the relative efficiency of triple and twin screws, rest on a somewhat slender basis.

I stand in a very difficult position in another way. It is this: I know a great deal more than I can say. It is not often that one is troubled in that way, perhaps, but in this case it is so. I have very exact information of the most scientific character, not merely of the performances of triple-screw ships, but of the comparison of such performances with model experiments, and I cannot (I wish it were otherwise) at this stage furnish the facts that are in my possession to the Institution, because they were given to me under the condition that they were to be for my personal information only. I must therefore confine myself to the paper. Taking the paper, what is said? First: that the use of triple screws leads to a considerable economy at high speed as compared with twin screws. I know of no conclusive

facts establishing that contention. Second: Admiral Melville recommends a third arrangement of triple screws. The first arrangement was with the screws of fairly equal size; the second, which has been boldly tried in Russia, where they have the courage of their opinions, was to have a very small screw in the center and two large screws at the side. Is it not a suggestive circumstance, gentlemen, that, trials having taken place with those two arrangements, we are now introduced to a third one, which puts the large screw at the center and the small screws at the side? I am asking for information. I do not know, but I say is it not suggestive? Then, again, the only fact of a numerical character that I find in this paper refers to the work involved in revolving the screws of a 12,000-ton triple-screw ship. Clearly, that is not an American ship, because there are only two triple-screw ships in the United States Navy, and they are, I believe, under 7,500 tons. Could we be favored with any statement of what this anonymous ship is, and how far these experiments went, or whether this is an estimate of power? Of course very much turns on questions of this nature.

Now, I would like to go further. Triple screws are recommended on the ground that they are a necessity under certain circumstances, and a particular example is given us of a ship which, I believe, is to be of 24 feet draught and 12,000 tons—I do not understand that she exists—and to be 22 knots speed. Now, what I have to say, with some knowledge of the subject, is that I should be quite prepared to undertake to produce a most efficient twin-screw ship to develop that power on that draught; so that, speaking with some experience, I say that that is not an example of the case which may arise—I always said it may arise. I foresee conditions under which it may arise, when we shall have to go on from twin screws to triples; but I do not think the example chosen by Admiral Melville is one where the necessity for more than two screws does arise. In fact, I may say that we are going to do very soon the very thing under discussion in a twin-screw ship.

There are various statements made in the paper which one cannot follow in detail, but which seem to me to indicate that

Admiral Melville has not that complete acquaintance with model experiments which we on this side possess. He speaks, for example, in a somewhat slighting manner of the information to be derived from experiments with model screws. If I may be permitted to speak with some authority, as I trust on this matter I do, I say that we are under the greatest obligations to model-screw experiments for our guidance in efficiently utilizing the large powers to which we have attained. And I will go further, and say that, on some occasions when, in order to experiment in the ship, which we always do—and, of course, I quite agree with Admiral Melville that the ship experiment is the crucial one—in some cases where, in order to get varying experiments, we have in one ship of a class put in our model experimental screw, and in another ship of the class put in a variant on that, we have often found it desirable to come back to the model experimental screw. So that I would like to record my opinion (which I am sure Admiral Melville will take in good part) that if he had a closer acquaintance with the application of model experiments to screws he would have much higher regard and respect for the results.

With regard to the remarks in the paper on the utilization of the frictional wake and the effect of shortening the shafts of the side screws, it appears to me the writer is only discussing tendencies; but it is necessary to ascertain the aggregate result of such changes on propulsion, not mere tendencies. It is a very interesting example of that to recall that the elder Mr. Froude, in his earlier work, as will be seen by a reference to the Transactions, favored very much the putting the single screws, which were then the common propellers, far abaft the hull of the ship, in order to diminish the augment of resistance; but, when experiments were made with screws as well as models, it was found that the balance of advantage did not lie that way.

As to the attitude of the Admiralty towards triple screws, I intend to say nothing except this, that, so far as I represent the Admiralty, the case was fairly stated two or three years ago in a book for which I am responsible, and anybody can read it for himself. He will find that, up to date, the decision has been

based on quite the conditions which Admiral Melville supposes. The question of draught has not been, and is not, the most important one to consider.

I should like, too, to have seen in the paper a more exact statement of what is involved in regard to internal space occupied, not merely by engine rooms, but by the shafting and the shaft passages in triple-screw and twin-screw ships. I can say this: that in vessels which carry the armament and the supplies of ammunition which those of the Royal Navy do, it would not be found a very easy thing to get a good stowage of ammunition in the after part of a triple-screw ship of the dimensions contemplated in the paper, and with three shaft passages running through in the finer part of the after body. In the Royal Navy it is the practice to endeavor to fairly equally distribute the ammunition at the two ends of the ship. We attach some importance to that in the consideration of armaments. These are considerations which press upon the designer of a warship: the best appropriation of the internal space is a most important matter, as Sir Edward Reed and everyone who has had to do with warship design will know; so that to discuss this matter from the point of view of propulsive efficiency only, would be to discuss it partially. One wants to look all around these matters.

I trust that in nothing I have said I shall have appeared to have been in the least forgetful of our obligations to Admiral Melville for giving us this paper. I have endeavored to point out that from the scientific and professional point of view it is not the sort of information we require to deal with this subject in a clear and conclusive manner. If he has that information, and is at liberty to give it to us, we should all be delighted and we should be under the greatest oligation to him. We certainly must look forward to higher speeds. We have to accept limitations of draught, and the time may well come—I have always thought that it may come, unless we change in a more radical fashion—when, if we persist in our present propelling arrangements and our present forms of propeller and types of machinery for certain classes of ships, triple or multiple screws will become the rule. But we are dealing with things as they stand up to

date, and my conviction is that no case has been made out in this paper for the alleged superior efficiency as propelling instuments of triple screws under the conditions prevailing in first-class battleships or large cruisers at high speed.

Mr. George Quick, Fleet Engineer, R. N., retired (Visitor): I have the misfortune to be merely a sea-going engineer. I have never built a ship or an engine, but I have had a great deal to do with both at sea. I have read a great deal of history, and the one lesson I have learned from it is that all the personnel and material of our navy should be organized for the supreme hour of battle and the week afterwards. I look upon our marine engines as fighting weapons, and not as mere economical machines to obtain the greatest amount of power out of every pound of coal. And I cannot help thinking that we shall have to adopt triple propellers for all our larger ships if we are to hold our own with other naval powers in actual warfare. Let us take the case of a twin-screw ship proceeding to China or any other distant station. During her passage out war has been declared, and one engine breaks down; then that ship cannot go into battle with a single screw only, for she would not possess sufficient speed, nor could she be steered well enough to take her place in line of battle. It would not matter what the power of that ship might be, we dare not take her into battle with only one propeller and one set of engines. Now, take the case of the triple-screw ship. She goes out to China or the Pacific, using her middle engines and middle propeller only, keeping her wing engines at rest and in perfect order. On her arrival she finds war has been declared, and serious defects are found in her middle engines, so that they are disabled, and would take some weeks to repair. But that vessel could go into action with her two wing screws. She would be practically a twin-screw ship, in perfect order, but of reduced speed, yet certainly fit for the line of battle. But, even if the passage had to be made at high speed, using all three propellers, the probability of safety is far greater with three screws and three sets of engines than with only two propellers and two engines.

I differ a little from Admiral Melville about the use of the screws. I should be disposed to work the middle screw only in cruising or in making ordinary passages, and should reserve the two wing engines and screws for going into battle, instead of working the wing screws for ordinary cruising. I wrote a paper on this subject in 1875, which was read at the Royal United Service Institution, in which I stated "that I did not consider that even twin screws gave that security for the propelling power which is now required by the exigencies of modern naval warfare." The watch-keeping naval engineer knows how easily an engine may be disabled in action. A splinter from a shell, or a broken bolt falls into one of our engines and it is disabled, and then, if the ship has only two screws, she becomes like a man with only one leg. But if the ship has three sets of engines and three propellers, and one of them is damaged in action, there are still left two sets, which would give very effective propelling power and steering efficiency under all conditions.

I agree with Admiral Melville that the middle engines should be more powerful than either of the wing engines, but scarcely to the extent he suggests. In the case of a triple-screw ship of 30,000 I.H.P., I should prefer to give 12,000 I.H.P. to the middle screw, and 9,000 I.H.P. to each of the wing screws. I feel indebted to Admiral Melville for his remarkably fair, clear and explicit statement of the case for and against the triple propellers. He has been a very busy man of late; he has had but a very small staff. He has been much overworked by the war, so that if there are any omissions in his paper I think we must put that down to the immense amount of work he has had; and, furthermore, I know that he was ill for some time lately. It is also quite possible that he does not consider himself to be at liberty to give further information than that which he has given us. We all fully recognize the tremendous work of the staff at our own Admiralty during the last year or two, although we have had no naval war, so I think we must also remember the strain on Admiral Melville's department if there be any shortcomings in his paper.

Lieutenant H. P. Norton, U. S. Navy (Member): My Lord and Gentlemen, I cannot make a full reply, but I would like to answer some of the points. This paper having been written by the Admiral, and I having been detached from duty in his Bureau before he commenced it, I do not know all the circumstances which have led up to its preparation; but I do know from his letter to me that every fact he has stated he has authority for, and if the Council will ask him, I am sure, if he is at liberty, he will add it to the discussion of what has taken place here to-day.

If you remember, we had triple-screw ships and twin-screw ships in commission during our late trouble, and, as mentioned in the paper, during the battle of Santiago our two fastest ships were practically of ordinary speed, because they could not stop to couple up the two spare engines. The problem is this: We have a ship, and we want to make 22 or 24 or 25 knots. She may make that two or three times during her commission—most of her cruising will be done at an average speed of 16 or 17 knots—but, if we can get a ship which is economical at 16 or 17 knots, we do not care what it costs to make the 24 knots. This is what this calculation is based on. We are now designing at home some of the largest battleships and cruisers of any navy, and this paper is the result of the calculations that have been made at the Bureau of Engineering for the propelling machinery of these ships. They are to be three-screwed ships using five-cylinder quadruple-expansion engines for the center screw, and four cylinders for the wing screws, the wing screws to be used together, or the center screw, and, whichever you are using, you can obtain 16 or 17 knots, and when you want the maximum speed you get it, and do not care what it costs.

I know a great many trials have been made with the *Columbia* and the *Minneapolis*, although I have not the data here with me; but I am quite sure it will be furnished when the Council ask for it. That is what has governed the Admiral in submitting this paper, and probably, had he anticipated the form the discussion has taken, he would have put the facts in. Regarding the question of electrical machinery, we went very heavily into that on the *Brooklyn*, and, as the result of her trials in the

Spanish war, we have decided not to duplicate it. You can tell what is the matter with a steam or hydraulic engine instantly; but you may chase for hours to find a broken circuit, and by that time the action is over, and you are out of the deal.

Sir William White: Is it not the fact that electrical power has been largely used for ordnance working?

Lieutenant Norton: Yes; but it is not to be used in the turrets, or the ordnance work of any of these ships, except for the hoist. That is the result of the fighting on the *Iowa* and the *Brooklyn*. Speaking of economy, the only question of economy in the engine forces which has been considered has been when working at ordinary cruising speeds. We do not anticipate an economical ship at both the maximum and the cruising speeds; we do not know how that can be obtained, but we should be glad to do it if we could.

About the couplings, we have no trouble in coupling up when the ship is going 17 or 18 knots. By means of a friction brake the screw can be held without any difficulty until the coupling bolts are fitted, as was done on board the *Minneapolis* when she was supposed to be chasing the Spanish fleet. As regards the two-bladed screws, as I understand the question, if you are going to propel the ship with a two-bladed screw, you have to have the same area as you would with three blades, and, as it is not the intention to secure the propeller when not in use, the frictional resistance would be the same whether the area is in two blades or three. There is no advantage in using the two blades unless you secure the propeller in the deadwood, which is not the intention in these vessels. I do not feel quite qualified to answer the other remarks.

The **President** (the Right Hon. the Earl of Hopetoun, G.C.M.G.): I feel certain, gentlemen, you will desire that the Secretary be authorized to convey a cordial vote of thanks to the Admiral for his admirable paper, and I think our thanks are also due to Lieutenant Norton for the excellent manner in which he has read the paper and in which he has replied.

The following communication was received from **Mr. S. W. Barnaby** (Member of Council):

I wish to say how much I appreciate this suggestive and valuable paper. Many years ago I expressed surprise that triple screws had not come more into favor for high-powered ships of war. It seems to me that the arrangement proposed by Admiral Melville has many advantages. Perhaps the most obvious is that upon which stress was laid in the paper, that is, that it fitted the ship, and if also it proved in practice to be the most economical disposition for cruising purposes, as Admiral Melville assured them that it did, then it seems difficult to resist the conclusion that the most logical arrangement of the motive power of warships is that proposed in the paper. The only thing to be said against the argument that greater efficiency of propulsion followed from the use of three screws because more advantage is taken of the beneficial influence of the frictional wake in reducing slip than is the case with twin screws, is that it would seem to lead to the conclusion that a single screw should be more efficient than twin screws for the same reason, and this did not appear to be borne out by experience.

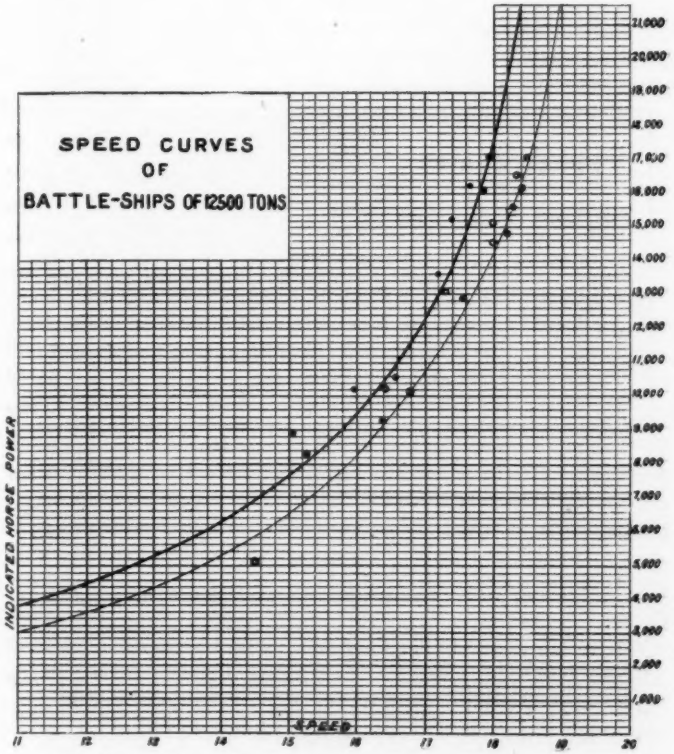
I am more disposed to lay stress upon the reduction of weight and improved economy at low powers made possible by their adoption than upon the probability of an improvement in propulsive efficiency attending the use of triple screws. Admiral Melville stated that in a ship of 12,000 tons, 22 knots and 23,000 I.H.P., having three equal screws, the power required to drag one disconnected screw amounted to 150 I.H.P. at 10 knots, and to 600 I.H.P. at 15 knots. When the middle screw is designed for half the power the resistance offered by it to being dragged through the water must be still greater, not only on account of its greater size, but also, I think, because the pitch rate would be finer, and I suggest that it might be worth while to consider whether it would not be found more economical to use one of the auxiliary engines, say a circulating-pump engine, made especially large for the purpose, to turn the center propeller at a rate of revolution corresponding to the speed of the ship, as it should take considerably less than 600 I.H.P. at 15 knots, and

less than 150 I.H.P. at 10 knots, to overcome the friction of the disconnected shaft and propeller. I suggest a circulating-pump engine for the purpose, because it could be conveniently placed at the after end of the engine room, near the shaft coupling. The center centrifugal-pump engine might be arranged either to drive the pump or the shaft, as required; but it seems to me that it would probably be most economical to enlarge one of the wing circulating engines, and thus avoid the friction and other wastes involved in the running of the third circulating engine.

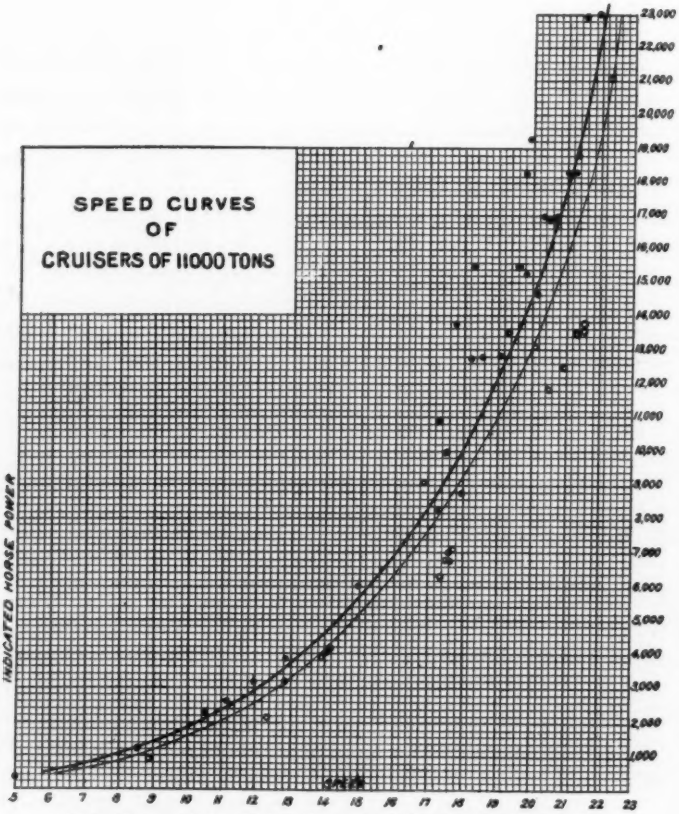
The following reply to the discussion has been received from **Rear Admiral Melville.**

I note that the principal desire expressed by the members of the Institution in regard to this paper is for more data. I fully appreciate the position of Sir William White regarding data which he is unable to publish. In fact, much of the information used by me in the preparation of this article is such as I feel unwilling to make public. I am, however, at liberty to give the results obtained from a consideration of the data, and I have done so. I realize that a considerable amount of detailed information which was omitted might have been included in the article. This omission was caused largely by my desire that the paper should not be too long for ready presentation before the Institution of Naval Architects. It was caused also by the fact that the number of trials from which the conclusions were drawn, something over two-hundred, was considered too small upon which to base any absolutely accurate figures, although establishing fully the general law. On that account such figures as have been included in my paper have been specifically stated to be tentative. They are subject to alteration as a result of future experiment.

I have attempted so carefully to avoid any exaggeration of the advantages of triple screws, that I think the figures enumerating the economic gains due to their use, both for high and low powers, will be found greater rather than less than those given in my paper. In deference, however, to the expressed desire of the Institution, I submit such data regarding the performance



THE UPPER (HEAVY LINE) CURVE FOR TWIN-SCREW BATTLESHIPS.
THE LOWER (LIGHT LINE) CURVE FOR TRIPLE-SCREW BATTLESHIPS.



THE UPPER (HEAVY LINE) CURVE FOR TWIN-SCREW CRUISERS.
THE LOWER (LIGHT LINE) CURVE FOR TRIPLE-SCREW CRUISERS.

of triple-screw ships as may be communicated without breach of a public trust. In this connection let me remark that I regret very much that Sir William White finds himself unable to give us the benefits of such model experiments as he may have made with triple screws. While I believe that no tests of propellers are so valuable as those obtained from the propellers themselves, in position on ships, where the theoretical conditions are thus minimized, and where we have to deal only with full loads and with service conditions, I am sure that it would be very interesting to compare these results with those obtained from tank experiments. It appears to me that such comparison would be a good test of the accuracy of model trials.

I append a speed and power curve of certain battleships reduced to 12,500 tons displacement by Froude's well-known laws of comparison, giving a separate curve to those ships fitted with triple screws. All trials from which these curves were constructed are of ships of approximately the same size, none of them being of less than 10,000 tons displacement. All belong to the same navy; they have the same character of hull and the same general under-water body. They are, in fact, almost identical in all respects, with the exception of the propelling machinery, and of the slight modifications in the under-water body necessary from the introduction of a central screw in the ships so fitted. Consideration of these curves will show at once that the power required is, in all cases, high in proportion to the speed. This is due to the peculiar character of the hulls in all of the ships considered. It is to be noted, however, that these characteristics obtain in the cases of the triple-screw battleships as well as in those fitted with a twin-screw system. The points marked by small circles and dots, respectively, are obtained from actual trials, and include the power of the auxiliary machinery.

I append also a speed and power curve of cruisers reduced to 11,000 tons displacement by the same laws of comparison. While these vessels are not so homogeneous in type as the battleships cited, it will be noted that there is with them about the same gain for the triple-screw system in the power required to attain a given speed. This difference is somewhat

greater than that which I have given in my paper as the probable advantage to be derived from the use of triple screws. Each point is from the actual trial of some cruiser, although they are not all from the same navy. Only a part of these trials includes the power of the auxiliary machinery. It appears to me that these curves, drawn as they are to give the fullest advantage to the system of twin-screw propulsion, develop fully the superior efficiency of the triple-screw system for full-power trials; or, indeed, wherever all engines are in use. However, as Sir William White says, the matter of the propulsive efficiency of the propellers is but one of the desiderata to be sought in the design of a naval vessel. I submit, however, that the superior propulsive efficiency of triple screws is an element of considerable advantage in their favor, although it must by no means be considered the deciding one. The deciding point in this matter seems to me to be the fact that naval vessels do at least 90 per cent. of their cruising at speeds below sixteen knots. In vessels of the fast type now so universally prevalent the condensation in the low-pressure cylinders is enormous when the ships are making these low speeds.

Mr. Barnaby has pointed out that the greater efficiency of propulsion incidental to the use of three screws, and consequent upon the utilization of the following wake, would apparently imply that a single propeller is more efficient than are twin screws. I have stated that up to a certain speed I consider that a single screw is most economical. Beyond that speed it is necessary to increase the size of this screw so greatly that the efficiency of the propeller is considerably reduced on account of the increased friction, and also on account of the increased difficulty of securing a free run of water to the blades. I am not sure when the critical point is passed. In the light of experience, however, it would seem that for ships having a maximum speed of as much as 15 knots the advantages due to the division of the propelling instrument into two screws are more than equivalent to the loss due to working these screws in the less advantageous position under the quarters of the ship. This may explain why twin screws are in many cases more efficient

than single screws. The use of triple screws, however, includes not only the advantages due to the use of smaller screws, but also the advantage due to the following wake. Triple screws must, therefore, always be more efficient than twin screws.

Data concerning the cruising efficiency of ships fitted with triple screws have been obtained from various sources. Tests of the steam consumption of the main and auxiliary engines of the triple-screw cruiser *Minneapolis* have been made. Trials have been made of this and other ships working with one, two and three screws at (A) constant speed; (B) constant power; (C) with a fixed coal consumption. Trials have been made of the *Kaiserin Augusta* (the details of which have been published) with and without a dragging screw. We have made trials of the *Minneapolis* at a constant speed and have measured the speed of rotation of the central screw (A) when revolving freely and (B) when connected with the central engine. Several twin-screw ships have been tried with one engine, with a resultant gain in coal consumption at the lower speeds when not only was there a heavy drag from the idle screw but also there was a considerable rudder resistance. Trials have been made of the *Kaiserin Augusta* working with one engine, (A) with the center engine and (B) with one of the wing engines, in either case the other screws being left to revolve freely. The difference in power required to attain a fixed speed in the last trials measured the resistance of the rudder.

The trials of the *Kaiserin Augusta*, which were conducted with great thoroughness, measured accurately the drag of the screw and also the resistance of the rudder; the latter being, at a speed of 14.1 knots, considerably more than twice as great as the drag of two idle screws when one of the wing engines was used alone. These trials developed fully the further fact that there is not sufficient propeller area in the central screw (the three screws being equal) to drive the ship economically at a speed greater than 9 knots. Trials of the *Minneapolis* were made with a constant coal consumption and working with both one and two engines and with absolutely the same auxiliaries in use in both cases. It had been found that the condensation in an engine

was approximately a constant, irrespective of the power developed, this condensation increasing slightly for the lowest powers. On these trials, with a fixed coal consumption, with two engines in use, 938 H.P. were developed, giving the ship a speed of 9.53 knots. With one engine only in use there was sufficient steam to give 1,236 H.P., though the speed of the ship did not exceed 9.36 knots. Knowing from previous experiments exactly the steam consumption per horsepower of these engines, it was possible to ascertain accurately the condensation, which was found to be, as has been stated in my paper, about one pound of water per horsepower of the maximum power of the engine.

The resistance of a dragging screw was measured in the experiments of the *Kaiserin Augusta*. It, as well as the engine friction, was also obtained on the *Minneapolis* in the following manner: The number of revolutions of the central engine when coupled with and turned by its dragging screw was observed accurately for a fixed speed of the ship, and also the number of revolutions of this screw for the same speed of the ship and when uncoupled from the central engine. The power developed by the propelling engines (the two-wing engines) was observed for the two conditions, and the difference between these powers measured the unloaded engine friction of the center engine. Further, on the assumption that the resistance of the dragging screw varied as the square of the difference between the number of revolutions made by it and the number of revolutions which would give it a zero slip, there was obtained the ratio between the resistance of the screw and the resistance of the engine and screw combined. The resistance of the dragging screw, ascertained in this manner, agreed very closely with that obtained from the results of experiments on the *Kaiserin Augusta*. It is of importance to note that the unloaded engine friction of the central engine was, at a speed of 10 knots, considerably greater than the drag of the central screw when the latter was left to revolve freely. If it be granted that the engine friction varies as the power of the engine (this is only an approximation of the correct rule), it is evident from the above that the horsepower required to attain a speed of 10 knots is greater with two en-

gines than it would be with one, if the latter has sufficient propeller area to avoid excessive slip. This is quite apart from the saving due to the decreased condensation of the engines. In fact, the *Minneapolis* ran at the rate of 9.73 knots with 1,872.6 H.P., and with one engine, while with two engines, to make a speed of 9.71 knots, she required 1,940.94 H.P. On the other hand, however, the speed of the *Kaiserin Augusta* was 9 knots with two engines developing 932 H.P., while for a speed of 9.07 knots with one engine 1,050 H.P. was required.

As I have said, in order that one engine alone may work properly, it is necessary that the propeller should be of sufficient disc area, which is not the case when the propeller is designed to transmit but one-third of the full power, and it is to this cause that I attribute the above comparatively unfavorable results. Experience with twin-screw ships has shown that propellers having a disc area of one-half that which is necessary to drive a vessel at a full speed of as much as 20 knots are efficient at ordinary cruising speeds. It appears to me that these results form a very strong argument against the use of a small central engine for cruising purposes.

The figures set forth in my paper as to the power absorbed in the drag of the screw are the maximum; those given as to the gains due to the use of triple screws under cruising conditions are minimized. Instead of stretching the case in favor of three screws, I believe I have done rather the reverse. I have been careful to give the established twin-screw practice the benefit of every doubt, which, I think, is quite proper. There are, however, a great many points in favor of the triple-screw system which are touched upon in my article and which have not been controverted in the least. I cannot say that I recommend the installation of triple screws in all naval vessels; but wherever as much as one-half the total power is sufficient to obtain a speed of, say, 16 knots, that system appears to me to be the only logical one to install.

The weight and cost of the machinery in a triple-screw ship is certainly no greater than for large twin-screw machinery of the same power. It is possible, as was shown off Santiago in

the case of the *Minneapolis*, to couple up, without damage, the central screw of a triple-screw ship while the vessel has a speed of 18 knots. This was actually done, and is an instance of the great tactical advantage possessed by triple screws over the method of arranging two engines on the same shaft—a system which our recent war experience will probably prevent us from installing in any future naval vessels.

In the discussion of my paper attention has been called to the engines not ordinarily in use under cruising conditions with triple-screw practice. I desire to call attention again to the fact that there is quite as much power not in use in twin-screw practice for the same ship and speed. Further, the idle power in triple-screw practice is maintained in much more efficient condition while cruising, and this with considerably more ease than obtains if all the machinery is in motion. The matter of the short lengths of shafting outside the ship with triple screws is one to which, I think, not sufficient attention has been paid. It would avoid the necessity for the 70-feet propeller shafts which, I believe, are now being used.

As to the space gained by the arrangement of triple-screw machinery proposed by me in this paper, I may say that, in a design now being prepared, it is found that the use of a large central engine and two small engines saves enough space below the protective deck from that required for twin-screw machinery to instal the evaporating plant of this ship and to provide for a pump-room. In Plate (see page 656, cross-section only) will be found a sketch of this design. It will be noticed that the central engine is a five-cylinder engine. This is intended to be used only in connection with the wing engines, and when the maximum power is to be developed. The wing engines are four-cylinder engines, and it is expected that these will be used during ordinary cruising. The number of cylinders ordinarily in use will therefore be but eight. No difficulty has been experienced in securing sufficient ammunition rooms, &c. The most serious problem has probably been the installation of the steering gear. The United States Navy had a twin-screw ship in 1862, the *Forbes*, and for river service in the Civil War had a great many multiple-

screw ships, called at the time "tin-clads." There was also the *Agamenticus* class of twin-screw monitors, constructed in 1863 for our Navy. These were four ships of something over 3,000 tons, and one of them visited the Thames something over thirty years ago. This was some time before Sir William White first advocated the use of twin screws in the British Navy.

The scheme proposed by Mr. Barnaby for working the central shaft by means of a circulating-pump engine would probably lead to a slight economical gain, on the principle that the engine efficiency will probably be greater than the efficiency of the dragging screw. I think, however, that the introduction of this feature will not lead to any very great saving, and it might interfere with quickly connecting up the central engine, at the commencement of chase, for instance. This is a detail, however, which further experience may, very possibly, show to be worthy of installation and of use, at least during ordinary cruising.

I am pleased to note that Sir William White says that a continuation of progress in design along present lines may lead to triple or other multiple screws being introduced into the British Navy. I believe that we have already arrived at the point where triple screws are considered necessary. In conclusion, I desire to thank the Institution for the discussion of this paper. I regard intelligent criticism, whether favorable or the reverse, as of much value in bringing out the points of any matter at issue.

OBJECT LESSONS.—THE LENS AND PENCIL IN MECHANICAL ENGINEERING.

By Lieutenant Commander A. B. Willits, U. S. Navy.

The illustration given in the May number of the Journal (page 446) of the results of galvanic action on a cast-iron propeller hub, where the blades and cone were of composition and the hull of the vessel itself copper sheathed, was an object lesson which needed but few added words of explanation, and readily fixed itself in the mind of the engineer glancing over the figure.

The force of a lesson of this character is greatly qualified by the amount of time it requires of the reader to comprehend it, and consequently, in these busy times in the mechanical world, where the rushing tide of progress is forever casting upon the shore all the inert elements of the crowd with which it teems, there is the greatest need of curtailing the elaborations of drawings and illustrations, and of reducing to the shortest possible amount the period necessary for a complete understanding.

In an original mechanical design or in a "lay out" for a machinery plant, the usual multiple drawings in plan, section and elevations must continue to hold their position of imperative importance. When, however, it comes to the matter of representing mechanical objects already existing, in order either to describe them or to call attention to defects, breakdowns or repairs, then a free-hand sketch, an isometric illustration, or a good photograph will be found to be far ahead of the "plan, section and elevation" in nine cases out of ten, both as regards expeditious production and ease of comprehension. Lengthy verbal descriptions are thereby also greatly curtailed and the danger of *pigeon-holing* much reduced.

The most progressive engineers "talk with their pencil," and when a clear mental picture is possessed by a good mechanic of

the object he desires to describe, the ability to make a quick and comprehensive sketch is not difficult to acquire and rapidly increases with practice. Unfortunately, too few persist in this exercise, so that instead of the possible reports of defects being rendered clear and easily *read* by a picture, we continue to receive long-winded descriptions " with attached blueprints," the latter often indicating laborious work on the tracing from which it was made, and not seldom being of a subject only requiring an exterior view to thoroughly elucidate.

In presenting the few object lessons selected for this brief article the work of the lens is employed in illustrating two of the subjects, and is of particular interest in view of the rapid growth of the use of the camera in mechanical engineering. This very truthful instrument has a superhumanly keen eye for exteriors and prospectively, with the X-ray adaptation, for much now hidden from view. When properly handled it can well serve to produce many working " drawings" (bar the word) even while showing a simple picture, as dimensions can be as readily marked on photographic negatives, and printed therefrom, as upon blue prints taken from such negatives. In marking on the negative proper any good opaque can be used, preferably upon the negative face, marking the figures backwards. Unless the negative is upon a celluloid film, marks upon the glass or back of the negative will not print clearly. With care in this work, requiring very little skill or time, a photograph can be made many times more useful than it generally is, and for repair work, where it is necessary to forward drawings showing the defects and requirements for new parts, a photograph will frequently be found most valuable. Much unfavorable comment and adverse criticism upon photography in engineering results from the misuse of the camera and the desire on the part of the operator to devote the principal portion of his work to the artistic instead of the useful; hence we have photographs of boilers of novel form, wherein, instead of the principal features with dimensions being included, the main object in view is the head of some boiler maker projecting from the manhole, or the superintendent of the boiler works in the

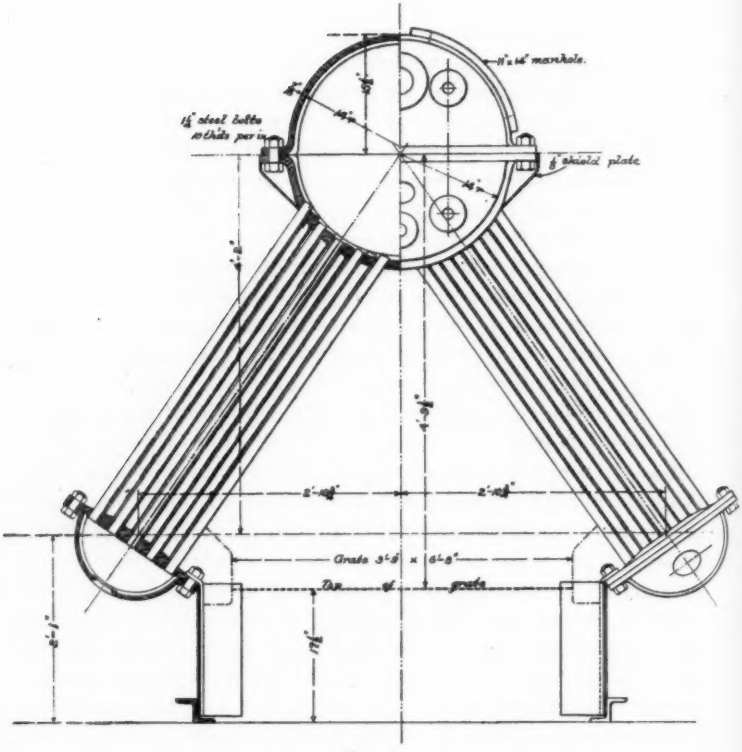


FIG. 1.

foreground with the boiler as an incident in the rear. To use the camera properly here, the principal object must be that of conveying useful information. With this in mind there is nothing more really helpful or any process that will repay the engineer better in its results.

The first figures (1 and 2) represent a section of a Yarrow boiler and a bulging of the upper part of the steam drum of the same, which latter occurrence took place during a recent voyage of one of our naval ships, the discovery of the bulge being only made after the ship came to anchor. In this case the close

approach to a serious accident is readily seen by inspection of the section of the drum in Fig. 2. These bulges occurred undoubtedly through a collection of soot upon these points taking fire and burning with sufficient intensity to overheat the shell. The coal used was of very inferior quality and undoubtedly lent itself readily to such an accident. The mishap, however, points most graphically to the necessity of protecting the upper parts of these drums from the possible collection of soot upon the metal. It is understood that this is now always done with the Yarrow boilers, but in the present case no protection had been

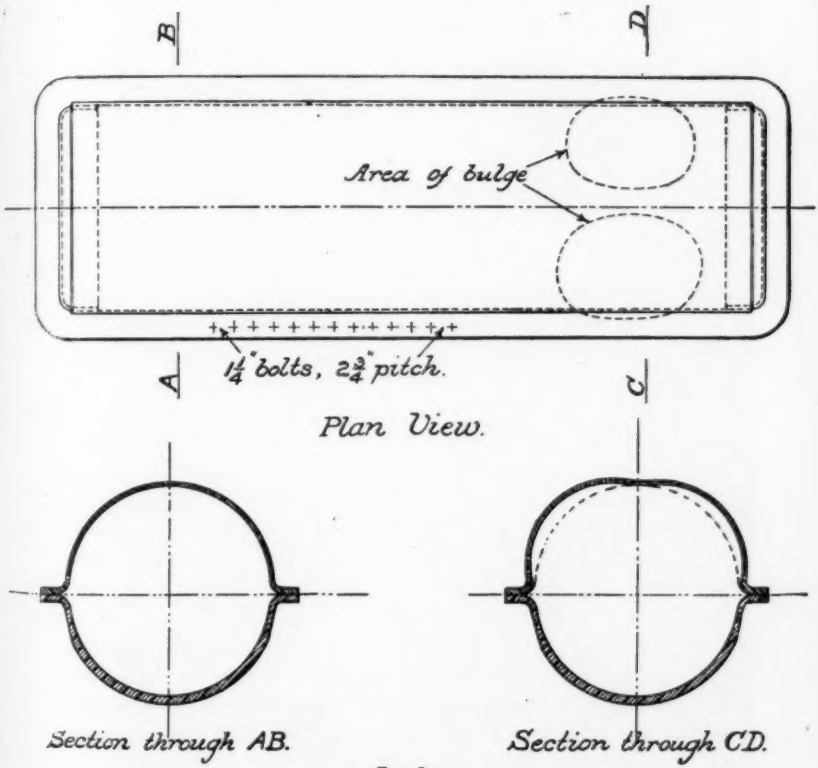


FIG. 2.

afforded. The steam pressure was about 200 pounds, and the metal at this section was so greatly overheated as to permit the expansion as shown over a considerable area and an opening of the inside portion of the flanges in the wake of the bulges. As it appeared that the metal itself was not seriously injured, efficient repairs were made by removing the flange bolts, one by one, opposite the bulges and reaming out the holes parallel, fitting in larger bolts with nuts on the upper end of at least one-half inch greater depth than the standard nuts. A cross slot cut in the top of the nut for the use of a heavy steel screw-driver wrench made the proper setting-up easy to accomplish in place. The top of the drum was then protected by a non-conducting material, and a deflecting plate for the gases fitted in the uptake. "Smooth-on" compound was put in the opened portion of the flanges on the inside, a suitable manhole plate in these drums rendering the work comparatively easy and the results eminently satisfactory for present use.

The allusion to a close approach to the danger line in the above "accident" (if it may be so called) brings to mind the condition of a 7-inch copper auxiliary steam pipe recently removed from one of our battleships. In illustrating this (Fig. 3) the camera has shown the condition far more graphically than right-line sketches possibly could. Numerous surface cracks, some of them very deep, were discovered in this copper pipe, and while a steam pressure of 160 pounds had been carried during the service of the same, a test application of 180 pounds hydraulic pressure burst the pipe. This pipe was supposed to be of excellent quality and was of No. 5 B.W.G., but the actual condition points to the necessity of the very closest inspection of all material used for pressure parts after the same has been formed into the shape desired.

From this figure one can readily realize how much a photograph of the steam drum defect (Fig. 2) taken from a proper position would have added to the explanation of the situation. This would have shown the bulges, bolts and general arrangement, but, owing to the confined space, as is frequently the case with machinery, it would have been difficult to secure.

FIG. 3.

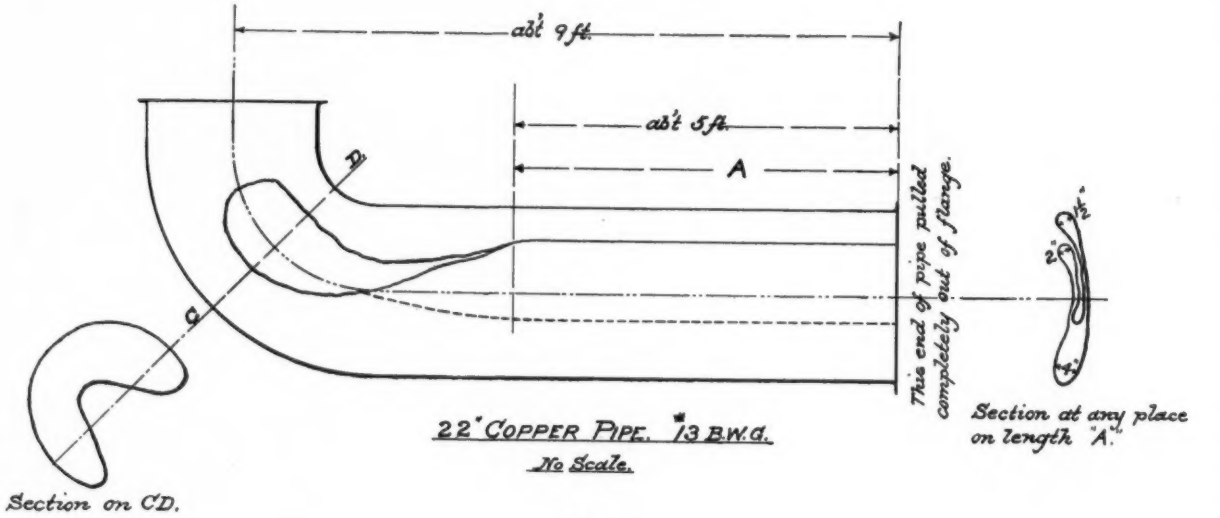

abt 9 ft.
abt 5 ft.
A
D
C
This end of pipe pulled completely out of flange.
2"
2½"
4"
Section at any place on length "A."
22" COPPER PIPE. 13 B.W.G.
No Scale.
Section on CD.

FIG. 4.

From the steam-pipe defect a most natural step is to the illustration of bad design in piping subject to exterior pressure. A most unusual accident recently occurred on a steam yacht whereby a 22-inch copper exhaust pipe, 13 B.W.G., collapsed under an ordinary vacuum of 24 inches. This is shown in Fig. 4, and was most complete in character, the section on length A, proving the pipe to be almost as perfectly flattened as it could have been under a hammer. The straight end of the pipe pulled completely out of the flange into which it was secured, the method of securing the flange having been by turning it over in a counter-bore. While accidents of this character are not considered among the elements of great danger, the occurrence points to the necessity of more carefully considering atmospheric pressure when partial vacuums are possible, either by accident or design, within the structure.

The engineer can seldom realize until too late the closeness to which the machinery of which he has charge approaches the danger limit in many of its conditions. This is most undoubtedly true in steam pipes, where the intense forces due to expansion by the heat of the steam bring abnormal strains upon flange joints, angles and castings, which, however, are rarely indicated by any show of distress before actual casualty occurs. The most serious consideration to be borne in mind for all steam piping is the proper arrangement of slip joints for the avoidance of such excessive stresses. The ideal arrangement for a steam pipe is to have risers at the boiler and straight leads to the engines. If it is necessary to have a drop at the engines by angles to reach the throttle castings, these angles should be anchored by heavy chain bracing to the protective deck overhead to relieve the end thrust on these parts, the same general idea being adopted for the riser at the boiler end, reversing the lead of "anchor" chains. The intermediate pipe should be supplied with proper slip joints which will then act the same as the piston in a cylinder, and no strain is brought on the intermediate flanges of the piping, except such as is due to radial pressure and against which it is easily possible to make tight joints. Even these slip joints, however, may prove to be a source of danger in a certain class of

boats (torpedo boats, for instance) whereby an accident can occur should the boat "take the bottom" and spring to such an extent as to draw the slip joints completely out. This actually occurred on one of the foreign-built torpedo boats, and in order to provide against this possibility Mr. Yarrow is now providing a trunnion joint (shown in Fig. 5), to which attention is invited as a particularly interesting and efficient feature.

Sources of danger exist often in hidden defects, especially in castings, and while the advent or advance of the mild-steel casting has decreased in a large per cent. the actual dangers due to shrinkage-cavities or blow-holes, owing to the fact that cracks do not as readily start from these as they would from the same in other metals, it is still well to understand where such defects are likely to be found.

The inferior fluidity of mild steel as poured in castings compared to that of cast iron includes a more rapid cooling and a greater difficulty in avoiding shrinkage cavities. This is well illustrated by a casting of the form shown by a section in Fig. 6. This section is from a short steam-pipe connection about 20 inches internal diameter and 3 feet long. The twelve ribs shown extended from end to end and into the flanges at both ends. The defects shown by the photograph exist opposite each fluting or rib where the metal is thickest. As the mold was made for the casting to be poured on end, the metal began to cool and solidify at the two surfaces (core and outside) very quickly after pouring, and, owing to the narrow section compared with the length of the casting, the fluid metal was unable to be fed properly from the heads during the whole process of cooling, the upper sections, solidifying beyond the flowing state before the mass was entirely solidified in the center, and when finally cooled the larger bodies opposite these ribs necessarily drew from the more liquid center, as shown, creating long shrinkage cavities in line with the ribs and nearly midway between the inner and outer surfaces.

All authorities agree that this is a difficult form to cast perfectly. The defect having been noted, the sink head would be made higher than usual, say for this casting 2 feet high, of

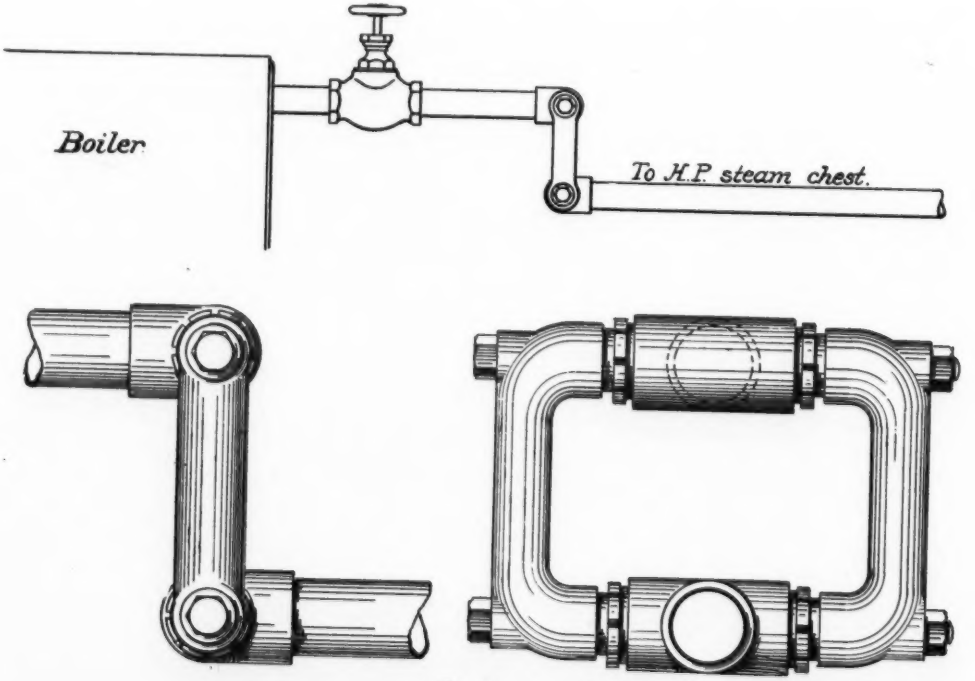


FIG. 5.

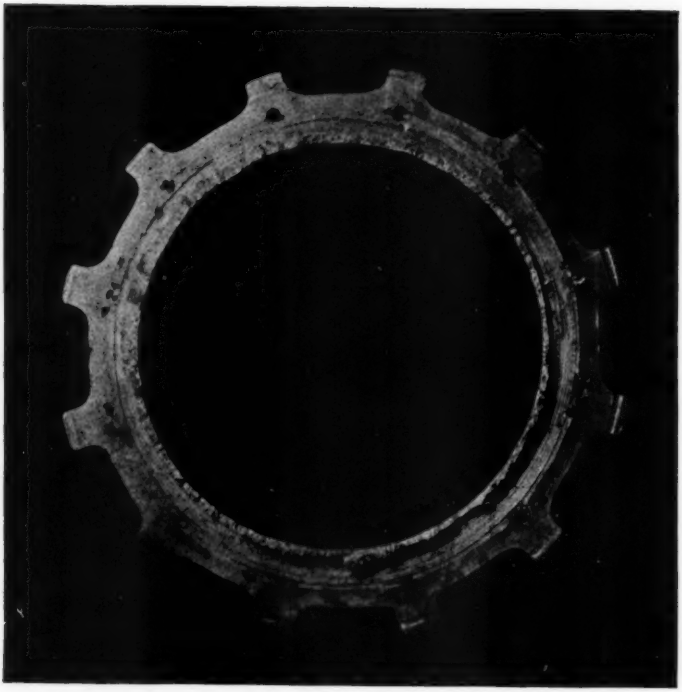
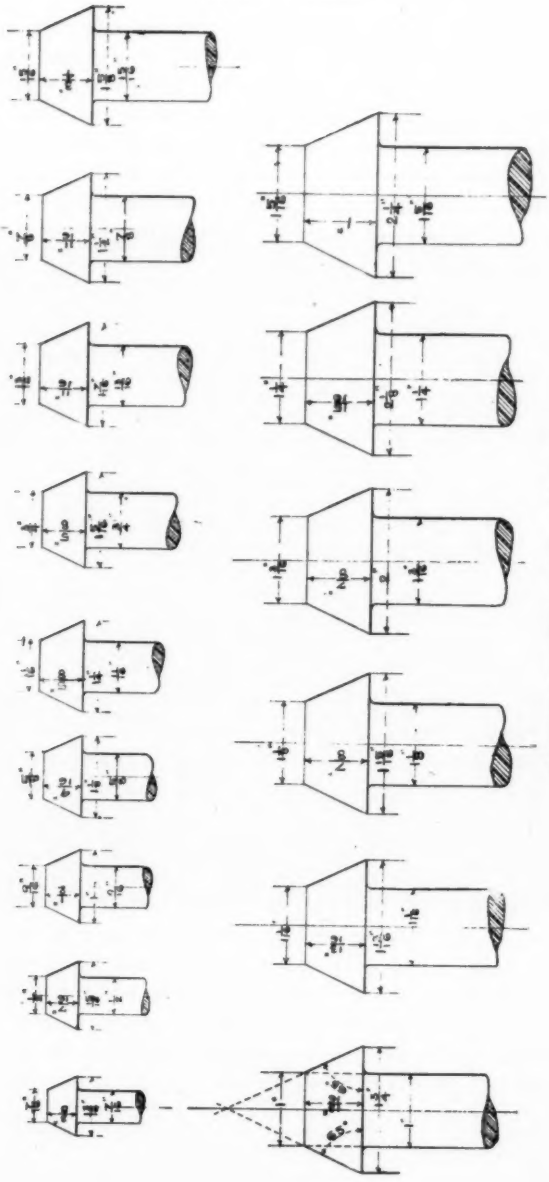


FIG. 6.

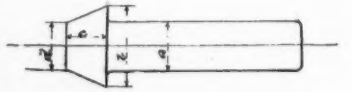
the full diameter of the upper flange and carrying the center core to the top of the head. Where great importance was attached to absolutely perfect casting, as in this case, it would be still better to increase the diameter of the center core very greatly and bore out from the center to the desired size, thus giving a greater thickness of feeding metal and throwing the possibilities of defects much further toward the center of the casting, where machining could clear them out.

The importance of properly forming sink heads for steel castings is still not understood by all foundrymen. Very frequently the idea prevails that a large, low sink head is as good as a high one, and many castings are made with short sink heads of large diameter having the neck or connection to the mold, greatly reduced, thus losing the best effect of a proper head. The "hydraulic" pressure, as it may be termed, of course, being indicated by the height of the head and not by the diameter, the question of height to bring proper pressure and a forced feed is a serious one; and while it may facilitate the separation of the head from the casting to narrow the neck, it is in many cases a most faulty thing to do, as the imperative necessity is to get a full and free supply of molten metal to feed as the casting proper shrinks in cooling. This feeding must not be choked and must be delivered as much as possible in the central or middle line of the casting. The large, heavy, full-sized sink head noted for the casting considered here, being the full diameter of the upper flange and extending all around the casting, if added to a decrease in the central core, as suggested, could scarcely fail to make such a casting perfect.

While on the subject of graphically representing details in machinery, the writer desires to allude to the advantage of curves and sketches over tabulated lists for many of the data necessary to use in engineering. This was brought to mind by considering the table of standard rivets used by the Bureau, and for which many demands have been made recently by outside parties. Diagrams of rivets of standard dimensions as furnished by the Bureau are given here, not only to illustrate this point but to serve any of the Society who may have occa-



STANDARD SIZES BOILER RIVETS, U. S. NAVY.



a	b	c	d	Wt of 10 Heads
7/16"	13/16"	3/8"	7/16"	.381 lbs
1/2"	15/16"	7/16"	1/2"	.531 "
9/16"	1"	1/2"	9/16"	.713 "
5/8"	1 1/16"	9/16"	5/8"	1.007 "
11/16"	1 1/4"	5/8"	11/16"	1.373 "
3/4"	1 5/16"	11/16"	3/4"	1.551 "
13/16"	1 7/16"	11/16"	13/16"	2.092 "
7/8"	1 1/2"	11/16"	7/8"	2.258 "
15/16"	1 5/8"	3/4"	15/16"	2.871 "
1"	1 3/4"	13/16"	1"	3.584 "
1 1/16"	1 13/16"	13/16"	1 1/16"	3.91 "
1 1/8"	1 15/16"	7/8"	1 1/8"	4.761 "
1 3/16"	2"	7/8"	1 3/16"	5.17 "
1 1/4"	2 1/8"	15/16"	1 1/4"	6.215 "
1 5/16"	2 1/4"	1"	1 5/16"	7.391 "

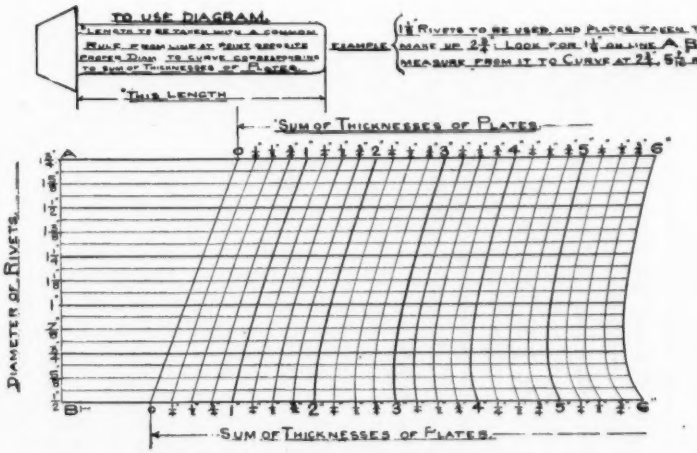

TO USE DIAGRAM.
LENGTH TO BE TAKEN WITH A COMMON RULE FROM LINE AT POINT OPPOSITE PROPER DIAM TO CURVE CORRESPONDING TO SUM OF THICKNESSES OF PLATES.
THIS LENGTH
EXAMPLE
1 1/8" RIVETS TO BE USED AND PLATES TAKEN TOGETHER MAKE 2 3/4". LOOK FOR 1 1/8" ON LINE A B AND MEASURE FROM IT TO CURVE AT 2 3/4". 5/8" REQUIRED
SUM OF THICKNESSES OF PLATES
DIAMETER OF RIVETS
A
B
0 1/4 1/2 3/4 1 1/4 1 1/2 1 3/4 2 2 1/4 2 1/2 2 3/4 3 3 1/4 3 1/2 3 3/4 4 4 1/4 4 1/2 4 3/4 5 5 1/4 5 1/2 5 3/4 6"
SUM OF THICKNESSES OF PLATES

DIAGRAM FOR LENGTHS OF RIVETS.

(CONSTRUCTED FOR HOLES DRILLED 1/16 LARGER THAN DIA OF RIVETS MACHINE RIVETTING BOTH HEADS ALIKE)

STANDARD-SIZE BOILER RIVETS, U. S. NAVY.

sion to refer to them. The diagrams are clear and far better in this form than they would be in a simple tabular one with columns for the different dimensions. Useful curves can be worked out to fit many occasions for which at present they are not used, and communications to the technical press during the last few years have indicated a greater attention to this matter by engineers. In the issue of the "American Machinist" of July 27th, Mr. J. E. Johnson, Jr., presents curves indicating the friction of compressed air in pipes, which are well worth the notice of all mechanical engineers of to-day, especially in view of the rapid advance of pneumatic tools and machinery in the industrial world.

LARGE ATLANTIC CARGO STEAMERS.*

[Reprinted from the "Engineers' Gazette."]

Since 1891, and more especially since 1894, there has been a great increase in the size of cargo steamers employed in the Atlantic carrying trades. This has been largely due to the foresight and enterprise, first, of Messrs. Harland and Wolff and the owners of the White Star Line, of Liverpool, and more recently, of Mr. R. S. Briggs and Mr. R. M. Hudson, Sunderland, Sir Christopher Furness, and Messrs. Elder, Dempster and Co. There is practically no limit to the size of cargoes that can be obtained in America.

It is remarkable that until 1895 there were no British cargo steamers of more than 6,500 tons gross register, except the *Bovic*, 6,583 tons gross register, and *Cevic*, 8,301 tons gross register, of the White Star Line, built by Harland and Wolff in 1892 and 1893; the *Samoa*, 6,839 tons gross register, and *Maroa*, 6,802 tons gross register, owned by Messrs. Crow, Rudolph and Company, Liverpool, and built by Messrs. W. Doxford and Sons in 1892 and 1894, and always excepting the *Great Eastern*.

Of merchant steamers (both for cargo and passengers), 6,000 tons gross register and over, according to a return of Lloyds' registry, there were building in March, 1895, ten vessels, and in March, 1899, fifty-four. Among the largest cargo, or partly cargo, steamers now building are the *Saxonia* and *Invernia*, of about 13,200 tons gross register, for the Cunard Company, by the Clydebank Shipbuilding Company, Limited, and C. S. Swan and Hunter, Limited, respectively. Of merchant steamers, 10,000 tons gross register and over (cargo and passenger), there are now building in British yards eighteen vessels, including the *Oceanic*,

*A paper by G. B. Hunter, Esq., Member, read at the summer meeting of the Fortieth Session of the Institution of Naval Architects, July, 1899.

about 17,000 tons; in German shipyards nine, and in French shipyards two vessels.

To illustrate the rapidity with which cargo steamers have been increased in size, and also the increasing adoption of twin screws, the following table from a paper read by Mr. E. W. deRussett, M. Inst. C. E., before the institution of Civil Engineers, with a slight addition, is given (all the more recent steamers were built for the Atlantic trade):

PARTICULARS OF SOME OF THE LARGEST CARGO STEAMERS BUILT EACH YEAR BY C. S. SWAN AND HUNTER, LIMITED, WALLSEND.

Year.	Name.	Dimensions.			Tonnage. Gross.	Water ballast.	Screw.
		Length. B. P.	Breadth.	Depth.			
		feet.	*ft. ins.*	*ft. ins.*		*tons.*	
1891	*Chancellor*	400	47–6	31– 6	4,753	831	Single.
1892	*Tokomaru*	425	53–0	34– 0	6,237	1,310	"
1894	*Aotea*	430	49–0	32–10	5,652	1,073	"
1895	*Westmeath*	450	56–0	34– 6	6,850	1,555	"
1896	*Milwaukee*	470	56–0	34–10	7,317	2,555	"
1897	*Monarch*	470	56–0	34–10	7,295	2,592	"
1898	*Mount Royal*	470	56–0	34–10	7,044	3,590	"
1898	*Ultonia*	500	57–4	37– 0	8,056	2,659	Twin.
1899	*Saint Andrew*	470	56–0	34–10	6,900	3,234	"
1899	*Invernia* (building)	580	64–6	41– 6	13,200 about.	4,550	"

Instead of singling out an existing steamer for description, some leading features of a typical American freight steamer of the present or early future, for carrying large cargoes across the Atlantic economically and safely, on a moderate draught was discussed. With docks, harbors and markets as they are and will be, such a vessel might be designed to carry not less than 12,000 tons deadweight, with cubic capacity for 20,000 tons of cargo at 40 feet per ton, and 1,000 tons of fuel. This would require dimensions approximately as follows: Length between perpendiculars, 500 feet; breadth, 60 feet; depth, molded, 36 feet to main deck; 44 feet to shelter deck. The draught of water, loaded, would be about 27 feet 6 inches.

The development of the Atlantic cargo steamship will be on ship-shape lines, and not in the way of fantastic patent ships. There should not be more than three complete decks, including a shelter deck, with a partial fourth deck in forehold only. The shelter deck is practically necessary for the American trade. The space covered by the shelter deck must necessarily be exempt from measurement for tonnage dues, except when used for freight or cattle. It is reasonable and necessary that it should be so treated, because it is not required for heavy cargoes, and adds greatly to the surplus buoyancy and freeboard, and to the safety of the ship and crew, while the expense of paying tonnage dues on this space when not carrying freight in it would be practically prohibitive. With a complete shade deck there is no need for the further addition of a long bridge house, either for more space or for safety, and such further erections are undesirable. Nothing more is advantageous above the shelter deck, in a cargo steamer, than houses for the accommodation of the officers and for sheltering the steering gear, with steering house and chart house 8 feet above the deck and pilot bridge 15 feet above it. With these the height from the keel to the pilot bridge will be about 60 feet. As an instance of a greater height, plans have been submitted to his firm for building a steamer over 90 feet from the keel to the top of the steering house.

The specifications should not be allowed to include any items that will not earn 20 per cent. per annum on their cost, to cover insurance, depreciation, interest and profit. The steel decks need not be sheathed with wood, neither should wood sheathing be fitted on the double bottom. He might pass over the question of cargo-discharging appliances beyond saying there is no need for a donkey boiler, and there should be not less than twelve to fifteen steam winches of the best description. It is a question for consideration whether there should be any masts, sails, etc., or not.

As regards strength, his experience has been that with good work Lloyd's scantlings for large steamers, with some little additions, have proved sufficient for Atlantic weather. The largest ships they had built had proved perfectly strong enough

after three or four years' work. Further experience is required to prove whether the larger steamships built on the present rules will stand ten years' heavy Atlantic work equally well. It is probable that they will. Those built by his firm are stronger in the shelter deck than Lloyds' rules require, but in other respects some of them are built simply to the rule scantlings. Of course it is necessary to pay special attention to the strengthening of deck and side openings, and to any places such as the ends of bridge deck house and the corners of hatchways where there is a sudden termination of a rigid structure or concentration of stresses. The number of rivets, spacing and size, also require special attention. The attachment provided by the latest rules for the frame feet to the margin plates of the double bottom is insufficient and should be greatly increased. Some other questions of local strength might be discussed, but structurally considered the materials and scantlings at present in use appeared to be sufficient.

Very few Atlantic cargo steamers have sufficient water ballast. From some of the Continental ports considerable quantities of outward cargo can usually still be shipped. From British ports, our somewhat one-sided free trade, together with the McKinley tariff, has so diminished exports to the United States that except to a certain extent by some special lines there is no outward cargo, or scarcely any, to be carried. It is necessary, therefore, to make the outward passage in ballast—that is to say, water ballast. The 500-feet, 12,000-tons deadweight steamer should have not less than 4,000 or 4,500 tons of water ballast, of which 1,700 tons can be carried in the double-bottom tanks, 2,000 tons in two "deep tanks," one aft and one forward, at about the quarter length, midway between the engine and boiler space and the stem and stern, and 800 tons in "'tween-deck" tanks between the main or upper and first lower decks. The latter are to be preferred for part, if not the whole, of the additional water ballast above that carried in the double-bottom tanks, not only in order to raise the center of gravity of the ballast, and so ease the motion of the vessel when rolling, but also because the 'tween-deck tanks, if properly designed, reduce broken stowage as com-

pared with the "deep tanks," and are more convenient for loading and discharging than the deep tanks. They should be fitted between transverse bulkheads the full breadth of the 'tween decks. The position of the deep tanks should not be immediately before or abaft the machinery space. If placed immediately before the boiler room, a deep tank will sometimes interfere with convenient bunkering arrangements, and in any case with the weight of the engines and boilers and of the bunker coals for both the outward and homeward passage, necessarily concentrated in the middle of the ship, 2,000 tons of additional weight as water ballast cannot be placed in the middle without causing some alteration of form, and also causing undesirable strains on the shelter deck, and possibly on the engines and shafting. On the other hand, large peak tanks in the extreme ends of the ship are undesirable as promoting pitching, vibrations and uneasy motions. A large addition might be made to the water ballast carried in the double bottom by carrying the inner bottom straight through to the shell plating at the upper part of the bilges, and he was not aware of any reason why shaft tunnels should not be used for water ballast, as had been proposed.

The questions of propelling machinery and speed are not at the present moment very difficult, with an exception that may be referred to further on. Large steamers are more easy and economical to drive than small ones. When they run in a regular line in turn with smaller steamers it is desirable for them to be fast enough to make up on the voyage for the longer time they take in port to load and discharge than the smaller steamers. In the Atlantic larger power is required than for Eastern trades. It is understood that one at least of the great lines trading to the East is carrying cargo at only 9 knots. With head winds, steamers of similar power to that in the Atlantic would be reduced sometimes to about 6 knots. The A steamer, 11,700 tons deadweight, and B steamer, 11,500 tons deadweight, steam 11 knots average loaded, consuming 45 tons per day of north-country coals; the C steamer, 10,700 tons deadweight, 12 knots, consuming 52 tons per day (those steamers have forced draft, but not Serve tubes). The three-cylinder triple-

expansion engines, with single-ended boilers working at 180 to 200 pounds pressure, and Howden's system of forced or Brown's system of induced draft are economical and durable, and as satisfactory, on the whole, as any other design that has been tried. This statement must be made subject to further experience of the effect of forced or induced draft on the durability of the boilers. It is largely a question of care and intelligence in working the boilers, but so far, with careful and skillful handling, there is no reason to believe that forced-draft boilers need be short lived.

The point of difficulty referred to is the question of shafting, and particularly of the propeller shafts. It is recorded in "Lloyds' List" that 173 steamships were disabled in 1898, mostly in the Atlantic, through fracture of shafting. It is stated that 53 similar accidents occurred in April, May and June this year. This can only be regarded as highly unsatisfactory. The causes usually assigned for these accidents are—the practice of steaming outwards from Europe to American ports in ballast—and generally with very insufficient ballast—the lightness of steel ships, and the reduction of their draught in ballast trim due to their floors and their lower lines forward and aft having been made so much fuller than formerly. He did not consider these causes entirely sufficient to account for the remarkable increase in the number of shafting casualties that has occurred during the last two years. They undoubtedly have much to do with the trouble, but some of them have been in operation for many years. It may be taken as established that the diameters of shafting, and particularly of propeller shafts, as required by the rules of the Registry Associations and the Board of Trade have been, and are still, insufficient. The Committee of Lloyds' Register have already increased their requirements for propeller shafts about 16 per cent., and it is believed that they have under consideration the necessity of a further increase. Greater attention is being paid to the protection of propeller shafts from corrosion and from sudden diminution of strength at the outer edges of the brass liners. These improvements will tend to diminish shafting casualties, but they will probably not be found sufficient

to prevent them. It may be necessary to go back to the practice of having an outer bearing for the tail end of the shafts, but, for reasons which we need not enter into, he did not recommend it. He should in large single-screw vessels for Atlantic service recommend increasing the strength of the propeller shafts 100 per cent. above the present rules.

There is reason to believe that during the last three or four years not only has the practice of running steamships across the Atlantic in ballast increased, but the captains and engineers, having grown bolder and more accustomed to it, have been less careful to slow their machinery down to half speed in bad weather when the vessel is pitching and racing badly. With the old compound engines governors were used, and were at least of some use, and in very bad weather the engines had to be slowed or the machinery would have been shaken to pieces. With three-crank triple engines, governors are less effective and are now seldom used, and the main engines are not so severely tried by running through heavy seas as with two cranks. But the propellers and propeller shafts bear practically the same strains with triple engines as with compound. The shafting is smaller in diameter, as compared with the power of the machinery and the size of the ships, than under the old rules for compound engines. The bending strains on the tail-end shafts when the propellers are only partly immersed and the blade strikes the sea are as great, if not greater, in new steamers than they used to be in the old compound steamers.

Considering the enormous and incalculable strains brought on the propeller shafts with the vessel pitching and the engines "racing," there is no reason for surprise that propeller blades and shafting are frequently broken at sea. Unless it be made impossible to run the engines more than half revolutions when in "racing" weather, it may be doubted whether an increase of even 100 per cent. above the present rules would be sufficient to prevent fractures.

For large steamers carrying 10,000 or 12,000 tons of valuable cargo, the ship and cargo being valued at perhaps £300,000, duplicate engines and screws should be provided. In addition

to the immense advantage of having an additional propeller in the event of one breaking down, the advantage of being able to use smaller screws when running in ballast is very considerable, and in a bad-weather passage will often shorten the voyage. It may be taken that twin engines increase the first cost, and usually increase the space occupied, and in fine weather are less efficient by about 5 per cent. Yet these disadvantages, together with, in most cases, a slight increase in the cost of working, are more than outweighed by the increased safety from breakdown and disablement at sea. In ships of about 500 feet long or more it may be said that twin engines are also necessary for handling the steamers in confined spaces.

It would be interesting to know the experience of other builders, but our own experience has been that the cost of building with the ordinary appliances is considerably greater per ton in very large ships than smaller ships. The cost per ton diminishes as the ship increases in size up to 5,500 or 6,000 tons deadweight, but gradually increases from 6,000 tons deadweight upwards. This increase is partly due to the larger ships being usually built on an improved and less simple specification, but is also largely due to the greater expense of handling the increased weight of frames, beams and other parts of the vessel, and the increased height to which the weights have to be lifted while building. The expenses of shoring and keeping very heavy ships in shape are also considerably greater, even than in proportion to the increased size of the ships.

The increased cost of handling the materials for big ships finally determined my firm to provide steam or electrical power, not only for hoisting the materials, but for transporting them and placing them in position. In considering the structural arrangements necessary for supporting overhead cranes, the advantages to be gained by protecting the workmen in our uncertain climate from the weather appeared so great that we determined to provide not only lifting appliances, but a complete shelter over the shipbuilding berths for the larger class of steamers we were building. They now, therefore, have covered-in sheds 500 feet long, with glass roofs and closed-in sides from about 14

feet above the ground upwards, over two of the building slips. In each of these, two electric traveling cranes are provided on rails running the full length, and with gibs revolving below the cranes, so that any part of the ships building can be reached. One of the shed roofs is also used to support an outside cantilever crane commanding a space of 500 feet in length by 60 feet in breadth, on which a third steamer can be built.

It has been found that the work can be carried on much more quickly and economically under those sheds than under the old conditions. It has also been found, contrary to the prophecies that were uttered, that the ships under the sheds are more comfortable to work at than the ships built outside. The temperature under the sheds is higher in winter and lower in summer than outside, and though they are open at the ends and at the bottom there has been no complaint of drafts. It has also been found that there is, together with a saving in the cost of staging and increased safety, a saving in the cost of shoring and fairing the vessels, as the columns supporting the roofs are freely used as abutments for the shores, which are consequently much lighter and more handy to use than if required to reach from the ground.

The one disadvantage (which was foreseen) is that although the roof and most of the sides are of glass there is a slight diminution of light, which has to be met with by increased use of electric lighting.

NOTES.

THE NEW GOVERNMENT TESTING TANKS FOR SHIP MODELS AT THE WASHINGTON NAVY YARD.

Many of our technical periodicals have recently published all the available data of these tanks, and have presented very interesting photographic illustrations of the several important features. We are forced to forego reproducing the illustrations, but the following description, reprinted from a paper by Naval Constructor D. W. Taylor, U. S. Navy, will be sufficient to impress a very clear idea of the structure and apparatus used:

The basin is located in the southeast corner of the Washington Navy Yard, and is enclosed by a suitable brick building 500 feet long and about 50 feet wide inside, the only openings being the doors and the windows in the monitor. The water surface in the basin is slightly shorter than the building, being about 470 feet long. The deep portion is about 370 feet long, the south end, from which runs begin, being narrow and shallow. The water surface is 43 feet wide, and the depth from the top of coping to the bottom of the basin is $14\frac{2}{3}$ feet. The basin is considerably larger than any other in existence. The nature of the ground was such as to render the construction of a thoroughly tight and stable basin somewhat difficult, but owing to the small space available at the Washington yard, it was necessary to locate it upon its present site. The bottom of the basin proper is made up of a layer of broken stone about 12 inches thick, upon which is a thin layer of concrete (about 3 inches), then a half inch of Neuchatel asphalt, then about 9 inches of concrete in sections 16 feet long, the keys between the various sections being filled with Bermudez asphalt, and the whole inside surface covered with the asphalt. The heavy side walls are 6 feet thick at the bottom, 6 feet deep, and about $4\frac{1}{2}$ feet thick on top, not counting the molded-stone coping. They are in 40-foot lengths,

with a square key hole between adjacent lengths filled with Bermudez asphalt. The side walls rest upon a double row of piles, and in addition there is a sheet piling completely around the deep part of the tank. The shallow part of the tank at the southern extension is also carried on piling, as it actually overhangs the water.

The law authorizing the construction of the model basin also authorized experiments to be made for private shipbuilders, provided they defrayed the actual cost of the same, it being understood, of course, that such experiments should not interfere with naval work. This being the case, it was necessary to lay out the plant with a view to the rapid and economical turning out of routine experiments, and to this end the endeavor has been throughout to use machinery for as many of the operations as possible. The foreign tanks invariably use paraffine for the construction of models, and generally make them from 10 to 14 feet long. The climate of Washington, however, is so warm in the summer that it was found impossible to obtain paraffine that would retain its rigidity satisfactorily, and, moreover, it was the desire of the Bureau of Construction and Repair to make the models as large as possible, thus eliminating one source of inaccuracy in applying the model experiments to full-sized ships. For these reasons wood was adopted as a material for the models, and after some difficulty a satisfactory varnish was found which rendered the surface of the wood to all intents and purposes absolutely water-tight. The standard length of model used is 20 feet. A model 20 feet long may not seem much larger than 12 feet long, but when it is remembered that the displacements of these two are respectively as 8,000 and 1,728, it will be seen that the 20-foot model is nearly five times the size of the 12-foot model.

The method of building the model is as follows: The "lines" of the vessel's hull as developed by its designers invariably include a body plan giving sections at moderately close intervals. From this body plan new sections are drawn to the proper size for a 20-foot model, by means of the eidograph or large pantograph. These sections are cut out of paper and then transferred

to wooden boards, which are sawed to shape. These boards are then erected in their proper relative position upon the erecting table, each board section being clamped in a vertical plane. They are then covered with battens about one-half inch thick, and tapering from amidships towards the end, making a "former" model, the surface of which is planed smooth. In cutting out the sections allowance is made for the thickness of the battens, which have to be nailed upon them. Meanwhile a rough block of such shape and dimensions that the finished model can be cut from it, has been prepared, by gluing together under pressure in a large hydraulic press, pieces of plank roughly cut to an appropriate shape. This block is placed upon the upper table of the model-cutting machine, the "former" model being placed upon the lower table. The model-cutting machine works upon the principle of the Blanchard lathe, a roller traversing the surface of the "former" model and saws or cutters working upon the surface of the model proper. The bulk of the material is removed from the block by means of the saws, which are shifted along a short distance at a time. Rotary cutters are then applied which finish the surface of the model very close to the desired shape. The model is then removed from the cutting machine and finished by hand; a very small amount of hand work, however, being found necessary. It is then ready for varnishing and the attachment of any appendages, such as bilge keels, struts, etc. It is finally taken to the measuring machine, and careful measurements are made of its exact form and shape, which not only enable the staff to determine whether the model represents the lines desired, but gives an exact record of the actual shape.

The model is now ready for the towing experiments. The carriage used in this work runs upon eight wheels and spans the full width of the basin. The platform in the center carrying the recording apparatus can be raised or lowered at will. Electricity is used to drive the carriage, and it may be mentioned incidentally that it is used for all mechanical work in connection with the model tank. The speed of the carriage is varied not only by making various combinations of the four motors—one to each pair of driving wheels—but by controlling the output of the

generator in the power station, which is, perhaps, 100 yards from the tank. This control is on the Ward-Leonard system, and is very similar to that used to control the motion of heavy turrets on board ship. By means of a resistance box on the carriage the current through the field-coil windings of the generator is increased or decreased at will. The revolutions of the generator being kept constant by a delicate governor, the amount of current generated varies with the amount of current through the field coils of the magnet. The whole of the current generated is passed through the motors, and in practice it is found that a very exact regulation of speed is obtained by this combination.

The carriage itself, with its fittings, weighs in the neighborhood of 25 tons, so that it alone forms a kind of fly-wheel, and is not subject to sudden variations of speed. The speed of the carriage can be varied from $\frac{1}{10}$ knot an hour, or 10 feet per minute, to 20 knots an hour, or 2,000 feet per minute. The principal difficulty in connection with the use of high speeds, which, while not necessary for the bulk of the experiments will be of great value in certain special experiments, is to stop the carriage when it is once under way. The electrical control acts as a brake, because when the current is shut off the motors become generators; but this could not be relied upon for high speeds, since the sudden rush of current due to possible unskilful manipulation might throw the circuit breakers, thus opening the circuit and cutting off the current entirely. For these reasons there is at the north, or terminal end of the basin, a double system of brakes to catch and stop the carriage. The first is a friction brake consisting of two strips of iron on either side pressed together by hydraulic cylinders. These are forced apart by a slipper on the carriage about 10 feet long, which, as well as the brake strips, is kept thoroughly oiled, so that the coefficient of friction for stopping, though low, is fairly definite and sudden jerks are avoided. The pressure in the hydraulic cylinders is controlled by an accumulator and a pump driven by electricity.

Great care has been taken in connection with this part of the installation that it may be always in working order, and any trouble or breakdown, except that of the pump itself, which runs

all the time, will simply result in setting the pressure at a maximum. This maximum is 600 pounds, but it has been found by actual experiment that with 500 pounds pressure the carriage is brought safely to rest when it enters the brakes at a speed of 20 knots. It is not expected in practice to repeat this often, since even for the high-speed runs the electrical brake will be used to reduce the speed of the carriage before the friction brake is used. In addition to the friction brake, there is what is called the emergency brake, so that in case the friction brake fails for any reason, the carriage would still be caught. This brake consists simply of a piston about 16 inches in diameter, working in a cylinder which is submerged in the water of the tank and connected by wire cables to a hook which takes hold of the carriage. The head of the cylinder has a round hole, and the piston rod is tapered so that as the rod is drawn out by the motion of the carriage the hole is gradually closed, the whole being almost exactly upon the principle of the hydraulic gun recoil brake. An escape is provided for the water around the piston when it starts from rest, to avoid sudden acceleration of the whole mass of water in the cylinder.

The dynamometric apparatus is designed to avoid entirely the use of multiplying levers or other devices involving the possibility of friction, and here again electricity is enlisted. The recording drum is, as usual, fitted with apparatus for recording the time and distance. The resistance is measured directly by a spring arrangement, which is placed underneath the carriage. The forward end of the spring is attached to a bracket which is screwed forward or back by an electric motor, and a rigid arm runs up from the bracket, with a pencil recording its position on the drum. The record then is of the position of the forward bracket. The after end of the spring takes hold of a small crosshead to the other end of which again is attached a towing rod, which takes hold of the model. This crosshead has a very slight play between stops in the after fixed bracket, and when it touches either stop closes an electrical contact which again throws an electric clutch, by means of which the motor, running all the time, screws forward or back the forward bracket, thus

increasing or decreasing the tension of the spring until the contact is opened again.

There are many refinements which cannot be indicated in this brief description; for instance, the operator can throw either clutch at will or set them to work automatically. In practice, when about to make a run, the operator works the bracket forward to the immediate vicinity of the position which he knows it will assume during the run, the approximate speed of which he knows. The carriage is then started, and after a uniform speed has been obtained, which, for speeds up to 12 knots, is done within 50 feet, he throws in by a single motion of one handle the automatic appliances which start the drum and record time, distance and resistance. In this way the resistance pen has to move but a small distance to reach the position of equilibrium and almost immediately becomes steady. With this device friction is eliminated. The accuracy obtainable depends upon the closeness with which the automatic stops at the after end of the spring can be set. In practice it is found that those can be set to give a play of about $\frac{1}{50}$th of an inch, and, as the springs will extend 10 inches, the results obtained are practically exact as indicating the pull of the spring.

It now remains to describe the method by which the amount of this pull can be determined in any instance. There is fitted at the starting end of the basin a kind of weighing machine with one vertical and one horizontal arm. This is delicately balanced, and when the model has been connected up and is ready for towing, a certain spring being in use, the vertical arm, or rather a knife edge which bears upon the vertical arm, is connected to the model. A known weight is then put into the scale pan attached to the horizontal arm. The automatic attachment in connection with the dynamometer spring is thrown into gear and the weighing machine is screwed forward or backward until it is in perfect balance, and the record pen recording the position of the spring is at rest. It is evident that the pull of the spring is exactly equal to the weight in the scale pan. There are a number of pens which can be shifted parallel to the recording pen and set in a definite position to record upon the drum. One

of these pens is set to correspond to the position of the resistance pen, then another weight is put into the scale pan, a second pen set to record the resistance, and so on. It is evident then that when the run is made these fixed pens mark off upon the paper a scale for resistance, avoiding all complications of corrections for temperature of spring or anything else. A complete double outfit of springs is already provided for measuring resistance from 1 up to 500 pounds, and for special work additional special springs will be obtained.

In connection with the question of temperature, it is impossible to avoid a certain variation of the temperature of the water, but as ample heating facilities are provided, it is not expected that the variation of temperature during the year will be sufficient to necessitate correction in the results of experiments on this account. The basin is filled from the water system of Washington, and will hold 1,000,000 gallons. Two electrical centrifugal pumps are provided, the larger of which will empty the tank in about four hours. The smaller pump is a 4-inch pump used for draining the last water from the basin, and also for pumping the water from outside the basin to avoid the possibility of undue pressure upon it in case it is left empty for some time. This is necessary, since the basin is but a short distance from the Potomac River, and extends 8 or 9 feet below mean low-tide level. A gage indicates the level of the outside water, which is found to be, as a rule, about 6 feet below the water in the basin.

The leakage from the basin, which is very slight, and the evaporation, are made up with filtered water, an animal bone filter being installed with a capacity of from 50 to 100 gallons per minute, depending upon the turbidity of the water. In practice, a small stream of fresh filtered water is kept running into the basin all the time and the level maintained wherever desired by an adjustable overflow.

Experiments are being made as opportunity serves upon models of the naval vessels already built and tried, for the purpose of accumulating data which will be constantly needed during the life of the tank. As soon as preliminary lines of the new third-class cruisers authorized at the last session of Congress are completed,

experiments will be made with them in the tank with a view to introducing any refinements or improvements found desirable.

SALE OF CONDEMNED WAR VESSELS.

On July 19, 1899, bids were opened at the Navy Department for several of the vessels purchased at the beginning of the war but which after the termination of hostilities were found to be unfit for service. The following list gives the details of cost and selling price:

Name.	Cost.	Appraised value.	Bid.	...
Governor Russell.....	$71,000	$35,000	$25,000	Withdrawn.
East Boston.....	57,500	30,000	38,091	Sold.
Vulcan.....	350,000	100,000	175,500	Sold.
Scipio.....	85,769	25,000	50,125	Sold.
Niagara.....	200,000	60,000	75,563	Sold.

The *Enquirer* was withdrawn and transferred to the War Department.

THE DAY OF AUTOMOBILES.

In speaking of this the Editor of the "Electrical World" says: If one thing stood out more prominently than another at the recent very successful electrical exhibition in Madison Square Garden, it was the deep impression caused by the electric automobiles shown there. Nor was the impression that of mere gaping wonder. It was largely a wealthy crowd that frequented the Garden, and the automobile exhibitors could have sold out their vehicles over and over again. It was also a varied crowd, for one concern alone, which sold some thirty carriages and wagons during the show, has to deliver the vehicles at about as many different points in this country and abroad. The orders and inquiries received by all the exhibitors leave barely a single part of this country untouched.

This is a striking manifestation of interest in the new departure, but the question remains to be settled: Who is to do the charging? And it is here that the alert central station

manager should find his new opportunity. It is not likely that all the business will come his way, but a large proportion will be his if he cares to develop a day load or to operate to advantage in the idle hours of midnight. The possibilities are these: There are said to be in New York City, for example, 5,000 ply-for-hire vehicles. If each of these took 50 cents' worth of current daily, as electrics, the consumption of current would reach not far short of $1,000,000 per annum, and it may be questioned whether another kilowatt of generating capacity would have to be installed to help furnish the current. Each manager can figure on the 'proposition' for his own locality.

But this is not all. One hears a good deal to-day of the severe limitations of electricity as compared with gasolene and naphtha. Something might also be said, per contra, about the severe limitations of gasolene and naphtha. There will be plenty of room for all classes of automobiles, but for ourselves we beg to be excused from the odor and jolting of vehicles propelled by gas, steam or oil. Electricity is, we must confess, good enough for us, and we believe that the facilities for charging electric vehicles will soon be abundant, not only within the cities but for many miles outside them, along every decent road. A time is rapidly coming when every enterprizing road house and country wayside hotel will have its little charging plant ready to start up and do its work while the driver gets his glass of beer and a sandwich. The same plant will do the lighting at night, and thus through the automobile electricity will have received the stimulus in rural districts for which it has long been waiting. This plan does not anticipate greatly the probable march of events in the next few years.

LIQUID-FUEL EXPERIMENTS.

While the Bureau of Steam Engineering has in hand the work of continuing experiments with liquid fuel and proposes to secure at an early date data that will be of real value, and upon which the question of the practical adaptability of heavy oil as fuel for our torpedo boats will be finally settled, it is interesting to note the discouragement which is felt by the English over

the failure of the experiments on the *Surly*. This, however, in no way prejudges our own results. The "Engineer" (London) of June 23, 1899, says: The oil-fuel trials in the torpedo-boat destroyer *Surly* have virtually been abandoned, it having now been demonstrated that unless special arrangements are made for consuming the smoke the adoption of oil as a fuel is impracticable. When the experiments commenced, about a year ago, great expectations were formed, as it was believed that the liquid fuel would be cleaner, cheaper and so far automatic in its feed as to save a considerable amount of labor in the stokehold. Throughout the whole of the trials, however, the *Surly* only once went to sea, and then it was found that, owing to the low evaporative qualities of the oil, the speed and power were far inferior to what would have been produced by coal. But it was hoped that by improved appliances to so obviate the escape of heat that this difficulty would be overcome, while the absorbing problem was the question of smoke abatement, and to this no solution has been found.

Had the authorities been resolved to create the maximum of smoke with the minimum of steam, they could not have succeeded better; but this was the exact opposite of what they were striving for. Nor was this one of those experiments that are foredoomed to failure, because the order was given that every mechanical contrivance was to be exhaustively tested until success was assured, but from first to last there was no diminution in the density, the dirtiness or the nauseous smell of the smoke.

Our contemporary, the "Naval and Military Record," finds comfort in the failure of liquid fuel, not merely because the adaptation of existing machinery to the new conditions would be expensive and tedious, but because it would be necessary to maintain reserves of oil at all the coaling stations, thus involving risks that are anything but desirable.

NAVAL STATION, CAVITE, P. I.

A very good idea of the facilities for repair work commanded by the Spanish forces at Cavite can be gathered from the fol-

lowing extracts from the journal of Naval Cadet Daniel S. Mahony, written while he was on duty there shortly after the station was taken possession of by our forces. It is frequently a marvel to naval officers to see the quite excellent quality of work that is produced with rattle-trap machinery at some of the foreign stations, especially where the natives have naturally the leaning towards mechanical arts and possess the patient manual skill that is found in the orient. Mr. Mahony says:

The naval station is situated on a peninsula between Baker Bay and Canacao Bay, the town of Cavite and Fort San Phillippe being also on the peninsula.

The buildings are old, and in no way suited to a modern engineering establishment. The first one contains the machine shop and blacksmith shop, with boilers and engines to run the same. Three heavy stone walls divide it into four parts.

The boilers are old-fashioned affairs on the Lancashire plan, furnaces running their whole length. The furnaces have Galloway tubes. Steam pressure is around 20 pounds, and much more would be hard to get with such a leaky combination of pipes and valves as is on these boilers.

The machine-shop engine is a vertical, direct-acting, single, inverted affair, feed pump attached, worked by an eccentric, and slide valve worked by a second crank. It is of interest solely as a relic.

The machinery in the shops is poorly placed. All of it is of the old, heavy type, and none of it good. The centers of most of the lathes wobble. The shapers are very old fashioned. There is only one gap lathe in the shop. There is no floor; the earth is rough and uneven, and the roof leaks. On one side the roof is of tin with large skylights, the other half of the shop has a solid roof and no windows on one side, so much of the work is done by candle light.

The blacksmith shop has modern forges, none of them very large. It has a blower run by belting from the machine-shop shafting. There is a large steam hammer valuable as a curiosity, and a small one somewhat better. There are no facilities for any heavy forging. The shop has the usual tools and French anvils.

The boiler shop is merely a big shed. It has five forges, two shearing and punching machines. There is also an immense old punching machine long past use: Power is furnished by a small horizontal engine, taking its steam from a Cornish boiler, of which there are two.

The foundry contains three brass furnaces and three cupolas, all of which need rebuilding, a small engine and a blower. There is no elevator behind the cupolas; all metal has to be carried up on the platform behind them. Their capacity is 1½ tons. A fairly heavy casting can be made directly in front of the cupolas, where is a track on which a truss is mounted on wheels. Heavy ladles can be swung from this truss. It is hard to say whether the natives do green-sand molding or dry-sand molding, as they use green sand and build fires under the molds. Cutting a pattern in two they never heard of, but with trowels and slickers they make very intricate molds.

The pattern shop is primitive. It contains a bench with one vise, a few chisels, planes, hand saws, bow saws and a lathe. The last consists of two parts: a table on which are two centers, one adjustable, and a wheel some six feet in diameter, much like a cart wheel. A piece of wood to be turned is placed on the centers, and a rope belt put around it and around the big wheel, and while two men turn the latter, a third holds the tool against the revolving wood. The natives much prefer, however, to sit upon a table, holding the piece of wood with their bare toes, and rounding it with a jack plane.

The marine ways are ordinary wooden affairs, a wooden bed sliding on rollers between wooden guides. The ways are moved by a large winch. The large ones are about 175 feet long and some 15 feet beam. The small ones are not over 100 feet long. The ways in the boat shed are an ordinary car track with a flat car on them. There is on the sea wall a large shears, good for about 25 tons, and a small crane, for perhaps 3 or 4 tons. These are the only lifting facilities in the yard. Both are worked by hand.

An old-fashioned car track runs around the yard, and there are a few flat cars, but no locomotives.

The shipbuilding shop is the most modern thing in the yard. It has two Cornish boilers, and two large horizontal engines, modern. They have good governors and an expansion valve. A third eccentric on the shaft works a feed pump, which takes a brine mixture from a well. The machines in the shop are all rather old fashioned, like everything else in the yard; still, if one can do with old fashioned things, there shouldn't be much trouble in getting along in a modern shop.

A large amount of work for the fleet has been done in the yard. In the foundry castings have been made for furnace fronts, bridge walls, pistons, pump chambers, etc., to say nothing of smaller articles. The blacksmiths have made heavy davits. In the boiler shop a boiler has had a new furnace fitted, been retubed, new stays put in; in fact, over half rebuilt. This work is worth bragging of, considering the means at hand.

THE COST OF LIQUID AIR.

Now that liquid air is easily procurable, at least in New York City and vicinity, by anyone who wants to dabble in it, and at a cost which is not prohibitory, the enticement to speculate as to its possibilities, and to practically experiment in its use, is an unusually strong one, and not without promise of profit.

In the present state of our knowledge, and with our present resources of skill, we must, of course, abandon from the beginning all expectation of being able to realize from the liquid air anything like the power that is employed to produce it; but, having thus given up whatever hopes we may have entertained in that direction, we immediately begin to discover conditions which strongly favor its adoption for certain purposes. The bugbear of power cost is worked for more than it is worth in many engineering fields, and especially so throughout the entire range of compressed-air service. Power is really one of the cheapest instead of the dearest things with which we have to do, although it must be carefully considered in many undertakings. The story of the employment of compressed air, now so extensive, is nowhere one of high economy in the use of the original

power, and in some of the most extensive and established applications of compressed air the losses, or, if you choose, the wastes, of power are enormous. But these very places, as, for instance, the air-brake service, and rock-drill mining, are the places where the alert readiness of the air renders it, after all, a most valuable and indispensable servant.

It will be interesting to note first what is the bottom cost of liquid air according to our present information. It is unnecessary, and it would, indeed, be foolish and unprofitable to attempt any minute accuracy in our estimate until the data upon which it may be based are close and reliable, as they certainly are not at present. We can, however, form a tolerably correct idea of what liquid air can be produced for, and at what price it will, before very long, be possible for the prospective user of liquid air to buy it.

In the "American Machinist," June 15, we have a little account of the interesting air-liquefying plant, in New York, of the General Liquid Air and Refrigerating Company. In the presence of this admirable installation Mr. Tripler's occupation as a producer of liquid air seems to be gone entirely. Here is a plant which, working at about 200 horsepower, will produce a gallon of liquid air per minute. In this simple statement is contained all that is necessary to enable us to approximately estimate (no guesswork about it) the cost of the liquid produced. It is a question of the cost of the horsepower used, and nothing beyond that, any more than there is anything else to be considered in the working of a pumping engine, or of the engines that drive a ship through the seas. There are practically no materials to be provided but the fuel, and the only labor is of the engineer and fireman class, with the necessary supervision.

The cost of power as developed by the steam engine varies widely according to the style of engine employed, and in a lesser degree it is affected by the local rates of fuel and labor and other conditions. The cost per horsepower hour has been computed and tabulated for all the various conditions, so that it is not at all necessary to compute them. In a table by the late Dr. Chas. E. Emery, which was published in the "American Machinst" April 1, 1897, the

total cost of a horsepower hour (covering coal, labor, supplies and repairs, sinking fund, taxes and insurance, with 5 per cent. added to total, and interest at 10 per cent.) is given as ranging from $0.0254 for an ordinary non-condensing engine to $0.00919 for a compound condensing engine, and $0.00811 for triple compound. If liquid air ever becomes a staple commodity, and one of the necessities of modern life, which is not impossible, it may safely be assumed that then engines approaching the highest economies will be employed in its production. For our present purposes I am disposed to assume $0.015 as the cost per horsepower hour, which is somewhat higher than the rate given in the table referred to ($0.0143) for an automatic cut-off, non-condensing engine.

In the plant we are considering, 200 horsepower produces 1 gallon of liquid air per minute. As a gallon of liquid air weighs (nearly enough for our purpose) 8 pounds, the 200 horsepower in one hour, or 200 horsepower hours, would produce $60 \times 8 = 480$ pounds of liquid air; so that 1 pound of the liquid would cost $200 \div 480 = .416$ horsepower hour. Professor Morton, by the way, computes the cost of liquid air as produced by Mr. Tripler at 10 horsepower hours per gallon, or 1.25 horsepower hours per pound, which is almost exactly three times as great as our .416 given above. As our cost per horsepower hour is $0.015, the cost of 1 pound of liquid air will be $.015 \times .416 = .0062$, and $.0062 \times 8 = .0496$—say 5 cents per gallon. This may be taken, I think, as a fair estimate of the cost of liquid air at the works. Milk retails in New York as low as three cents per quart, or twelve cents per gallon, so that we may some day see liquid air selling as low as cheap milk, although it may still be some time before it is commonly used.

Having the liquid air thus begging to be employed, the next thing to promote its use is the facility with which it may be transported. No franchises and no favors are required from any municipal authorities. There need be in its interest neither pipe-laying nor wire-pulling. Any truckman may carry the liquid anywhere. Stores of it may be established at different points, so that anyone could replenish his supply without going far.

Supposing vehicles to carry liquid air for propulsion, no time would be lost in recharging.

I am not here advocating the use of liquid air for vehicle propulsion, or for any other purpose, but simply trying to get an idea of the prospective cost of the liquid for anyone who may propose to use it. It is not likely that, for a considerable time at least, the air will generally be procurable "at cost," as I have here figured it; so that if anyone is thinking of using it, say for automoblie work, he must put his figures much higher than mine as here given. And then the constant loss of the liquid by evaporation, the leakage over the top of the vessel which contains it, must never be lost sight of. There is no way in sight of storing liquid air tight and safe; so that practically it must be used nearly as it is produced. It will not keep over night. The loss may be kept quite low with suitable insulation, and the larger the quantity stored, the smaller the proportionate loss; but still the pull will be unremitting, and all in one direction.—Frank Richards in "American Machinist."

NEW DRY DOCK FOR THE BOSTON NAVY YARD.

Work has already been commenced on this dock, and it is to be completed within thirty calendar months.

The borings made at the site of the new dock show that at a depth of about 25 feet below mean low water a bed of compact clay and gravel is encountered, with some thin sand strata, possibly containing water. The position of the new dock is about midway between the old stone dry dock, finished in 1833, and the larger of the two "wet basins," and parallel to the old dock. The general dimensions of the dock will be as follows.

	Ft. Ins.
Length on coping, from head to outer end of table	788–0
Length on coping, from head to outer gate sil	750–0
Length on floor, from head to outer gate sill	729–0
Length on floor, from head to inner abutment	689–0
Width on coping in body	114–0
Width on floor in body	72–0
Width on coping at abutment, least	101–8⅝
Width at entrance on mean high-water level	100–0
Depth from coping to mean high water	5–2
Depth from coping to floor, in body	39–2
Draft over sill at mean high water	30–0

Under the terms of the contract this dock is to be built of concrete, with-rubble stone fillers, and lined with cut-stone masonry. When the excavation has sufficiently advanced so as to fully expose the character of the underlying material, the Government will decide whether piles shall or shall not be used under the dock; the present borings, however, would indicate that the soil is sufficiently compact to omit piling. A price for piling and framing, in accordance with plans made, was obtained in the bids submitted, to be separately considered. In addition to the dock, there will be a pump house, one story in height, built of granite, with steel roof trusses and copper roof. The necessary culverts and wells will be made of concrete and lined with glazed brick. There will be three main drainage pumps, of the centrifugal type, with separate electric motors, balanced and driven by vertical compound engines, and four steel boilers will be included in this plant. The steel caisson, or floating gate, with all its pumping plant and machinery, is included in the bid for the complete dock; but a separate item covers the steam generators in the central power house, the pumps, engines, dynamos, electrical capstans and winches, and all piping and connections, and all machinery, excepting the machinery in the caisson. The contractor is also required to excavate a channel from the entrance to the dock, and one foot below the table end of the dock, to a point in the harbor where a corresponding depth is reached.

The pumping plant will include three independent centrifugal pumps, with separate motors, for pumping out the dock; and one centrifugal drainage pump and motor. There will be two vertical, cross-compound, condensing, automatically-governed engines, with each engine connected with two dynamos; and also four steel boilers. The pumps admit water on both sides of the disc, and the runner shaft will be directly connected with the armature shaft. The general plan calls for an average discharge for each pump of 43,000 gallons per minute; the minimum required mean discharge duty of the three pumps is thus 135,000 gallons per minute, measured while pumping from mean low water to floor level. The efficiency of the machinery in the

pump well must not be less than 55 per cent. The main pumps, as designed, contemplated a 6-vane runner, 79 inches diameter, a single 45-inch discharge pipe, and two 32-inch suction pipes, joined by quarter-turn bends to each side of the pump casing, and inclosed runner, so as to balance the runner and avoid end thrust. There will be three double-gate valves to each pump; one on the discharge and one on each suction pipe. The drainage pump will have a 34-inch runner, and be direct-connected to an electric motor placed on the same bedplate; the suction and discharged pipes will be 14 inches diameter.

There will be four 200-kilowatt dynamos, of the compound-wound, direct-current, constant-potential, 125-volt type, arranged for direct connection with overhung armatures. The fields are to be multipolar; and the commercial efficiency of the dynamos must not be less than 92 per cent. with full load; 90 per cent. with half, and 85 per cent. with quarter load. One 300-kilowatt motor will be directly connected to the runner shaft of each of the three main pumps, and one 50-kilowatt motor will drive the runner shaft of the drainage pump. Each engine, running two dynamos, will run, condensing, with 100 pounds initial steam pressure and 26-inch vacuum, and develop continuously 600 I.H.P. The working boiler pressure will be 125 pounds gage, and the speed of the engine is to be 150 revolutions per minute, with a variation in speed not exceeding 1 per cent. with any change of load.

The steel caisson, or floating gate, will have an extreme length of 104 feet $2\frac{7}{16}$ inches; molded breadth, 22 feet; and a depth of 36 feet 5 inches from the bottom of keel to the under side of upper deck. It will be built, as far as possible, of open-hearth steel, with welded members of wrought iron. The keel and stems must be 30 inches wide, outside of channels, and made of two 15-inch by 55-pounds channels connected to side plating by rivets spaced $4\frac{1}{2}$ inches on centers. The transverse frames are spaced 24 inches on centers, alternating 5 by $3\frac{1}{2}$ inches by 13.6 pounds, and 5 by $3\frac{1}{2}$ inches by 17.8-pounds Z-bars.

The channel for gate packing, running the entire length of the

keel and stems along the outer edge on both sides of the caisson, is steel, 10 inches by 25 pounds, fastened by $\frac{7}{8}$-inch rivets. Inside these channels is fitted a thick rubble packing secured by an oak timber 5 inches thick. In the hull of the caisson will be 13 20-inch valves connected with 20-inch wrought-iron culverts, for flooding the dock, and there will also be two 20-inch sinking valves for use in settling the caisson into place. The centrifugal pump in this caisson will have a capacity of 3,000 gallons per minute with mean lift, and it will be driven by an inverted, vertical engine of acceptable design. The bottom of the caisson will be filled with Portland cement concrete ballast, and there will also be sufficient movable cast-iron ballast to give the caisson a floating draught of 18 feet 6 inches.

The six electric capstans, three on each side of the dock, will each be operated by a 22.5-kilowatt motor, contained in a pit 5 feet deep under the capstan. Three electric winches, of about 25 kilowatts each, will also be installed, one at the head of the dock and one on each side of the entrance. There will be a separate underground circuit leading to these capstans and winches from the power plant.

The completion of this dock will be one of the most important steps towards promoting the Boston Navy Yard to the rank held by the yards at New York and Norfolk, that of a first-class modern repair station.

THE INFLUENCE OF CASTING TEMPERATURE UPON STEEL.

In a recent paper Robert Abbott Hadfield says: This question is especially surrounded with difficulties on account of the fact that the casting temperature of steel is only known approximately, even with the latest form of pyrometers. Useful work has been carried out in France with the Noel and Mesuré optical pyrometer, but while it is claimed that much has been learned from its use, at the best it only gives approximate results. Seeing that Mr. H. H. Campbell, in his excellent paper on "The Open-Hearth Process" (American Institution of Mining Engineers, 1895), states that even a difference of 20 degrees to 30

degrees centigrade causes considerable changes in the behavior of molten steel during casting, it will be understood how important it is that a thoroughly practical pyrometer, which would enable us to detect such differences, should be perfected. Mr. Campbell's remarks on this subject are so important that it may be well to quote them fully. He states that an addition of 100 pounds of scrap to a 7-ton bath (100 pounds ÷ 15,700 pounds) will cause the temperature to fall about 16 degrees or 20 degrees centigrade, and that this variation is perceptible to the naked eye.

An excess or deficit of (500 pounds ÷ 15,000 pounds) in the addition of scrap on the same weight and heat makes the charge either so hot that it causes trouble, or so cold that it skulls badly in the ladle. A variation of 200 pounds from the true amount, which would show by calculation a variation of about 30 degrees centigrade, is the greatest error allowable in good practice.

Incredible as it may seem, within these narrow limits lies the success of the blower and the melter. Perhaps the best practical pyrometer available, naturally varying according to individual circumstances, is practical observation by the eye, as there are no absolutely correct data as to the temperature at which steel should be cast. If steel is cast too hot the ingots or castings are liable to be piped considerably, even though the utmost care be used in pouring, and there are other difficulties, such as segregation. If cast too cold the metal produced will not work as satisfactorily as it should do during forging, and the ingots will probably be round and unsatisfactory on the exterior.

A very peculiar appearance is noted in crucible steel which is cast too hot; it is usually known as "scalded" steel. The crystalline structure is very pronounced, but by careful reheating the peculiar appearance noticed seems to disappear, though it is questionable whether the product is even then entirely satisfactory. In a recent correspondence of the writer with Messrs. Huntsman, of Sheffield, who still carry on the manufacture of crucible cast steel, founded by the well-known inventor, Benjamin Huntsman, in 1740, it was stated that to obtain the best quality, scalded steel could never be retreated except by remelting. It will be seen, therefore, that the greatest possible care

should be taken to have the steel prepared during its course of manufacture in such a way as to obtain the happy medium of temperature, that is, neither too hot nor too cold; but until more perfect pyrometers are produced this can only be obtained with constant liability to error.

TABLE I.—*Showing Colors of Steel at Various Temperatures from 650 Degrees to 1,300 Degrees Centigrade.*

Hadfield.

Color.	*Temperature.*	*Color.*	*Temperature.*
White,*	1,240	Bright red,	923
High yellow,	1,130	Medium red,	795
Yellow,	1,081	Blood red,	667
Low Yellow,	971		

Pouillet.		*Bowker.*	
White,	1,300	White,	1,204
Orange heat,	1,100	Very bright red,	1,010
Cherry red,	800	Bright red,	926
Red heat,	525	Full red,	804
		Red heat,	650

The table of temperatures, Table I, has been found very useful by the writer in everyday work. The first part represents the author's results obtained by means of a Le Chatelier pyrometer suitably protected in the furnace; this pyrometer is an admirable one so long as it does not come in contact with molten metal. Part two represents similar comparative temperatures taken from Pouillet's tables, and part three is from a table prepared by an American expert. There is also added in Table II the melting points of various metals, also the temperatures noticed during industrial operations obtained by Mr. H. Le Chatelier and others, both with electrical and optical pyrometers; these are in some cases necessarily approximate for the reasons before given.

* Not welding heat.

TABLE II.—*Temperatures in Degrees Centigrade of Melting Points of Various Materials.*

		Degrees.
Melting point of	Sulphur,	448
	Gold,	1,045
	Palladium,	1,500
	Platinum,	1,775
	White swedish (4 % carbon),	1,135
	Gray-foundry iron (3½ % C, 1¾ % Si, ½ % P),	1,220
	Soft steel (0.10 % C),	1,475
	Hard steel (0.30 % C),	1,455
	Hard steel (0.90 % C),	1,410
6-ton converter,	In the ladle,	1,640
	In the ingot mold,	1,580
	Reheating furnace,	1,200
	Ingot under steam hammer,	1,080
Siemens-Martin furnace (steel containing about 0.30% C):		
	End of fusion period of cast iron,	1,420
	Refining point of the steel,	1,500
	Steel in the ladle (commencement),	1,580
	Steel in the ladle (end),	1,490
	Temperature of gas from producer,	720
	At the entrance to the regenerator,	1,400
	When leaving the regenerator,	1,200
	When arriving at the chimney stack,	300
Siemens-Martin furnace,		1,600
Rotating puddling furnace,		1,230 to 1,330
Blast furnace working on gray Bessemer near tuyeres,		1,930
Commencement of the blast,		1,400
End of the blast,		1,570

STORAGE BATTERIES.

The growth of storage-battery service in this country has been slow and the development of the industry of its manufacture has been marked by a succession of failures. In spite of the adverse conditions which have surrounded the introduction of this useful

appliance, however, the advantages to be derived from it are so great that it has come to be employed on a very large scale, both in lighting and power stations. The great importance and economic advantage of the storage battery as a supplement to dynamos of central stations and in isolated plants was recognized and taken advantage of at a much earlier day on the Continent of Europe than in America.

In 1892 one of the things which surprised the American visitor at the Electrical Exhibition in Frankfort was the great size of the storage plants installed there. The time has now come when we do not need to cross the water in order to see storage batteries of large capacity in daily commercial use, and, indeed, some of the largest installments of this kind are to be found in our American cities.

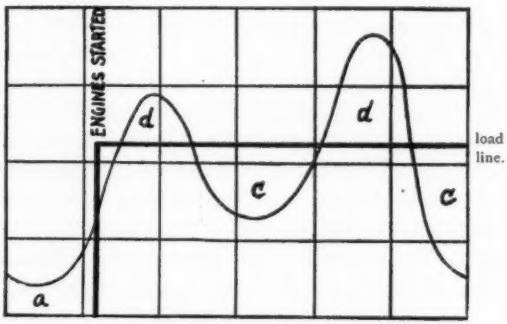
When we inquire into the reasons for the delay on the part of American engineers to take advantage of the storage battery, we find our answer in the fact that for many years it was impossible to purchase at any price batteries capable of giving satisfactory service. That time is past, and we can now obtain such batteries, but the introduction of them on a large scale is still greatly impeded by the high prices at which they are held. If we consider, for example, the relation between the cost of crude copper and the cost of copper made up into insulated wire, and compare the margin existing in that industry with the margin which exists between the price of lead and its oxides, and the price of the same materials when combined in the cells of a storage battery, we obtain a very good indication of the backward state of the industry of manufacturing these batteries as compared with the advanced state of many other industries. No better criterion, perhaps, can be had in such a matter than the relation between the cost of the manufactured article and the crude material from which it is made. Storage batteries in large sizes, where a single element, for example, weighs one hundred and fifty pounds and upwards, are quoted at about thirty-five cents a pound. The price per pound of the materials which go into such a cell are probably not more than one-sixth of the above.

Of the two processes invented, respectively, by Planté and Faure

for the production of the plates of secondary batteries, that of Faure appeared for many years to have supplanted the earlier method of Planté altogether in commercial practice. At the present time, however, both processes are used in modified form. The modifications in the processes of Planté consists chiefly in previous chemical treatment of the lead plates for the purpose of hastening the electrolytic or forming action of the current. For this purpose numerous pickling baths have been proposed, the first of which, consisting of nitric acid, was due to Planté himself. Other liquids are frequently used, but in general the principle is simply that of starting the oxidizing process at the surface of the metal.

A great variety of modifications of the grid which forms the skeleton of all Faure plates and which holds the active material applied to this type of battery in place, have been devised, the object in every instance being the same, namely, to provide a form which shall hold the oxides most securely and thus obviate the annoyance and difficulties arising from buckling and from the shedding of the paste on the surface of the plates. Many elaborate forms of grid have been made to attain this end, but the difficulty can be successfully met by very simple means. Some home-made batteries, constructed for the purpose of testing this matter, were made by slitting quarter-inch lead pipe lengthwise with a saw and building up a grid consisting of the narrow leaden troughs thus produced, one above another, until a framework of the desired dimensions was attained. These strips were held in place by casting around them a frame of lead. It only remained to fill the interstices of this rudely-constructed grid with the active material and subject the plate thus manufactured to the forming action of the current in order to make an excellent storage battery. The cells thus produced were given a long series of tests in the laboratory, for the purpose of determining the quality of their performance. It has been found that they compare favorably with the best types of storage cells now on the market in durability under widely different conditions of service, including heavy discharge and irregularity of service, such as is rarely expected of batteries in commercial use. The expense ac-

counts of making a battery of such cells, even without the appliances at the hand of manufacturers, show that the statement made in the opening paragraphs of this paper, namely, that the margin between the cost of raw material and of the manufactured product is in this industry of unwarranted size, was fully justified. Counting the price for labor at rates in excess of those which would be paid by manufacturers of such articles, and taking the cost of the raw material at the market price which the small purchaser has to pay, it was found that such cells could be turned out for less than one quarter of the price charged for such storage batteries as are upon the market in this country.



(a) Battery carries entire load.
(d) Battery carries peak of load.
(c) Battery receiving charge.

FIG. 1.

The most important function of the storage battery of the present day is that of supplementing a dynamo and steam plant in power and lighting stations. Nearly all such stations are compelled to work under conditions requiring a twenty-four-hour service with highly fluctuating load. Both for lighting and for power as applied to traction there are short intervals of time during which the load rises to values far above the average. These "peaks" on the load curve occur as a rule, both for lighting and street traffic, during the morning and evening. The two curves coincide or overlap so that a combined power and lighting ser-

vice has no better distribution of load than either one taken by itself would have. Indeed, the combination serves rather to aggravate the evil. In both cases we have comparatively light load during the middle of the day and during the late hours of the night, and yet in ordinary stations of considerable size current must be maintained upon the line during these slack periods.

Numerous devices have been tried for the purpose of maintaining a reasonably high efficiency of operation of power and light plants under these adverse conditions. Of these the most successful by far is the storage battery. The nature of the problem may be most easily discussed by means of a diagram showing the load curve for such a station (Fig. 1). On this diagram I have indicated the distribution of work for engines and batteries in order to show the way in which it is possible by use of a battery of sufficient size to equalize the demands upon the steam plant.

It is obvious first of all that in order to carry the load during the hours of maximum demand, boilers, engines and generators must be of much greater capacity than that required for the average load of the day, unless they are supplemented in some manner. This means excessive expenditure of capital, and it means the running of steam engines under conditions of poor economy during the greater part of the day. By the introduction of a storage battery it is possible in many cases to cut the size of the boilers and engines down by at least fifty per cent., which is an important saving in first cost, and to run these engines and machines at full load during the whole time that they are in operation. This means further saving. The manner in which the storage-battery service is combined with that of the steam plant is as follows:

From midnight, at which time the engines are shut down, until 5 A. M., the storage battery, previously charged, carries the entire load. This allows an interval of five hours, during which the engines are allowed to rest, which is in itself a desirable feature of this system. At 5 A. M. the engines carry the load, and in addition charge the storage batteries up to the time when the load has reached a value equal to the full capacity of the steam plant. From this time on the storage battery shares the

load with the engine, taking everything in excess of the above-mentioned value. When the load falls again after the passage of the peak of the curve below the full capacity of the engines the batteries are again charged. On the approach of the second peak they are discharged once more, carrying the excess of load. During the early part of the night there is again a time during which the load is rapidly decreasing, when they can be further charged. At midnight the engines are stopped and the storage battery carries the night load as before.

Another position in which storage batteries are found very useful is in sub-stations situated near the terminals of long trolley lines and other lines for distribution of power. It is obvious that by the location of such a battery of suitable size for the work, the amount of current which has to be conveyed to the distant point need never exceed the average load beyond that point, whereas without such a supplementary service the lead wires must be sufficient to carry the maximum load required at the sub-station. The saving in copper thus made goes a long way towards paying the expenses and maintenance of the battery. The manner in which such a battery is to be utilized in a sub-station is obvious. During times of light load the battery is charged by means of the excess of current. When the load exceeds the average, the battery supplements the current from the central station and obviates the necessity of overloading the lead wires.

As an equalizer of potential upon trolley lines with automatic devices for immediate charge or discharge of the battery with every fluctuation, excellent success has been had in a number of instances. It has been found in the case of the electric road at Zurich, Switzerland, where this system has been in vogue for a number of years, that storage batteries will stand up under the very irregular and exacting service required of them in such work in a satisfactory manner. The rapidity with which such a battery is alternately charged and discharged is shown in Fig. 2, which is a diagram covering a half hour of the record of the Zurich station.

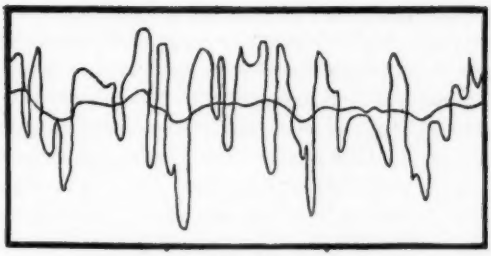


FIG. 2.

The very irregular line shows the variation for the station as a whole, while the nearly horizontal line shows the part carried by the engine. The storage battery is alternately charged and discharged to meet the demand of the moment.

Compared with the service demanded from storage batteries in the central and sub-stations and in isolated plants for light and power, the other uses are as yet comparatively insignificant. They are, however, very numerous, and taken in the aggregate would in themselves constitute a considerable industry. That these miscellaneous uses of storage batteries are on the rapid increase goes without saying, and that they may in course of time greatly exceed the uses described in the foregoing paragraphs is highly probable.—E. L. Nichols in the "Sibley Journal."

PRODUCTION OF IRON AND STEEL IN THE UNITED STATES.

According to the publication entitled "Statistics of the American and Foreign Iron Trades," for the year 1898, the production of iron and steel has greatly increased in the United States. In 1898 was witnessed the beginning of a movement in the iron trade of this country that has produced a revolution, the progress of which is being watched with the deepest interest by all exporting nations. This movement is no other than the consolidation of iron and steel firms, in order to create new corporations, which already control a capital estimated at more than $500,000,000.

From these statistics it is ascertained that the exportation of

iron and steel and manufactures thereof in 1898 amounted to $82,771,550, against $62,737,250 in 1897, and against $48,670,218 in 1896, which shows an increase in two years of more than 70 per cent. Included in the exports of 1898 were 253,057 tons of pig iron, 291,038 tons of steel rails, 28,600 tons of ingots, blooms and billets, 18,510 tons of steel-wire rods, and 24,195 tons of other steel rods and bars, 27,075 tons of steel plates and sheets, 74,665 tons of wire, 15,735 tons of cut nails and spikes, 13,714 tons of wire nails and spikes, and 34,038 tons of structural iron and steel. There were also exported 580 locomotives and large quantities of machinery made principally of iron and steel.

In the above figures agricultural implements are not included, the exportation of which amounted in 1898 to $9,073,384, against $5,302,807 in 1897 and $4,643,729 in 1896. The importation of iron and steel by the United States has greatly diminished as a natural consequence of the enormous home production. Iron and steel, and manufactures thereof, were imported in 1880 in amounts aggregating $80,443,362, and were exported only in quantities valued at $15,156,703. In 1898 the amount of those articles exported represented a value of $82,771,550, and the importation of the same was valued at only $12,473,637, which shows that the conditions existing nineteen years ago have been entirely reversed.

The American manufactures of iron and steel compete favorably with the English, even in the domain of Her Bratannic Majesty. There are shipped to-day from the United States to England and her colonial possessions considerable amounts of pig iron, steel billets, steel rails, steel plates, structural steel, wire rods, wire nails and cast-iron pipe. Lately an order has been received for 60 American locomotives to be used on two of the great railways running from England to Scotland, the Midland and the Great Northern. As a remarkable fact we may add that the British Government has ordered in the United States a steel railroad bridge, consisting of seven spans 150 feet each, to be placed over the Atbara River in the Soudan. The Baldwin Locomotive Works, of Philadelphia, is now filling an order for 45 locomotives for railroads of India. The Pennsylvania Steel Com-

pany has a contract for the construction of a steel viaduct, 2,260 feet long and 320 feet high over the Gokteik Gorge, in India. This work will cost $700,000. The Russian Government has ordered from the Phœnix Bridge Company, of Phœnixville, Pa., 12 steel railway bridges, etc., etc.

During the year 1898 the consumption of pig iron in the United States averaged a little over a million tons per month.

The exportation of iron and steel first exceeded the importation in value in 1893. Five years later, in 1898, the exportation of those articles exceeded the importation by $70,297,913.

In 1898 the exports of agricultural implements amounted to $9,073,384, against $5,302.807 in 1897. Mowers formed more than two-thirds of total value of these exports, for they alone represented $6,551,741.

The total production of pig iron in the United States during the year 1898 amounted to the enormous aggregate of 11,773,934 tons against 9,652,680 tons in 1897, which shows an increase of nearly 22 per cent. In the same year, 1898, the production of Bessemer steel ingots in the United States amounted to 6,609,017 tons.

The total weight of Bessemer steel rails in 1898 was 1,976,702 tons. The production of all kinds of steel in the same year was 8,932,857 tons.

It is estimated that the total consumption of iron ore in the United States during the year 1898 amounted to 21,193,000 tons.

THE BOILERS OF WAR VESSELS.

The "Engineer's Gazette," of August, 1899, thus alludes to the discussion of the boiler question for British war ships: There is no more important question at the present time in connection with the Royal Navy than that of securing durable, economical and safe boilers, which can supply high-pressure steam with rapidity without endangering their efficiency. Now all these requirements cannot be complied with by the ordinary marine boiler, and however much firms who have the requisite plant for making the "tank" boiler may be disinclined to hasten the adop-

tion of water-tube boilers generally, they, as well as other less interested parties, are practically compelled to admit that it is impossible to revert to the use of the cylindrical boiler. While that is the case there still remains the very important question as to what water-tube boilers should be adopted. So far as the practice of the British Admiralty has gone the Belleville boiler has been solely adopted in vessels of large size, such as battleships and first-class cruisers, but there are not wanting signs that in this matter there will be a change and that other water-tube boilers will be adopted, free from "the great complications of detail and accessories" which was pointed out by Mr. F. T. Marshall in his paper on "The Boiler Arrangements of Certain Recent Cruisers," read at the recent meeting of the Institute of Naval Architects at Newcastle-upon-Tyne, to be one of the objections to the Belleville boiler.

The paper just alluded to is one of the most important contributions that has been made to the literature of the modern water-tube boiler, and while in it is to be found all that the writer could apparently see his way to state on behalf of the Belleville boiler, which has been manufactured under his direction and fitted by his firm on board of H. M. S. *Andromeda*, still to an unbiassed reader what he adduces against the Belleville boiler far away surpasses in importance any apparent advantages the boiler appears to have over water-tube boilers with fewer complications. He points out that a "grave objection" to the Belleville boilers "is the enormous mass of mechanical detail in connection with them. Thousands of joints, all dependent upon extreme accuracy of workmanship, and many of them subject to extreme strain, due to varying temperature, are a pronounced feature in the design of this type." * * * "The feeding is also extremely delicate, owing to the small quantity of water contained, and also to the variable weight of this water at different rates of evaporation. This latter condition necessitates the introduction of the hot-well pumps and large feed tanks. The feed regulator employed" is, Mr. Marshall truly says, "a delicate mechanism, and has to be kept in a high state of efficiency."

Referring to the large number of boilers necessitated in a vessel

on account of the small size of the Belleville boiler, while admitting that subdivision of power was not without some advantage, he was compelled, on the other hand, to state, "but it certainly causes an enormous addition of important detail, such as feed-pipe and steam-pipe arrangements, all requiring care and attention," and that "the furnace air-pumping engines are also an additional complication, involving many extra fittings."

Now, while this paper was being read Sir John Durston, the leading engineering adviser of the Admiralty, was present, as was also a representative of the Belleville boilers' patentees, but in no way did they controvert what we have quoted from Mr. Marshall's paper. Sir John Durston practically confirmed the statements in it, as he described the comparison made in Mr. Marshall's paper as fair from the writer's point of view. There appears to be no reason whatever to imagine that Mr. Marshall has any interest antagonistic to the Belleville boiler; his "point of view" is to our mind that of a careful and skilled observer, and as such his views are of great weight.

It is unfortunate that the Admiralty have been committed to such an extent to the adoption of the Belleville boiler, and, naturally, that body will have great reluctance in acknowledging their error. Still, as we have already indicated, and not before time, there are signs that the Belleville will not remain the favorite water-tube boiler of H. M. Navy. The Chancellor of the Exchequer in his reply the other day to the strictures of Mr. Wm. Allen, M. P., defended the adoption of the water-tube as opposed to the cylindrical boiler, but not the Belleville as against all comers. The well-known engineer, Mr. Penn, after throwing out the suggestion of having on one vessel two different designs of water-tube boilers, one being of the small-tube type and capable of working under forced draft, and the other the Babcock and Wilcox, or other horizontal, straight tube type, concluded by hoping that the Admiralty would ultimately "adopt the best type."

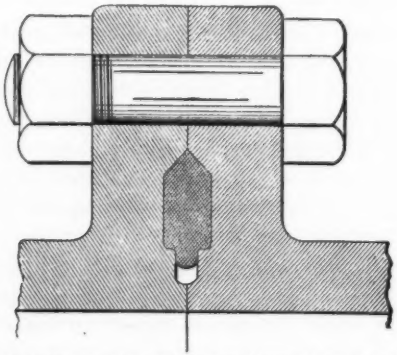
Now it does appear that simplicity of design must be a feature in a permanently successful boiler, and it may now be safely affirmed that straight tubes are a *sine qua non*, whether they be

placed vertically or horizontally. In this respect the Yarrow, Babcock and Wilcox and the Belleville boilers may be said to be on an equality, but excepting this feature the latter boiler has no claim to be of simple design.

The fact that a series of tubes are connected together on an element, and if one tube be choked the circulation of the whole of that element ceases, is to our minds a fatal flaw in its design, and, together with the other complications to which Mr. Marshall directs attention, is sufficient to condemn it as a boiler for a British war vessel in the opinion of any unbiased engineer.

A PIPE JOINT FOR HIGH PRESSURES.

During the discussion of Mr. Nagle's paper on "Pipe Flanges and Their Bolts," at the recent Washington meeting of the American Society of Mechanical Engineers, the following remarks were made by Mr. Halsey. They show a novel and highly success-



CAPTAIN RAPIEFF'S PIPE JOINT FOR VERY HIGH PRESSURES.

ful form of pipe joint, and one which we believe has not before been brought to public notice.

"The sketch, which is made from memory only, shows a form of joint with which I became acquainted some years ago, and which was so satisfactory under trying conditions that it deserves to be more widely known. It was invented by Captain Rapieff

for use with the dynamite gun—that is, the gun commonly known as the Zalinski gun. The joint was applied to the gun itself (which is in sections) and throughout the pipe fittings. The receivers are sectional with numerous connections, and positive tightness and reliability are essential. The firing reservoir, the gun and the intermediate connections operate under a pressure of 1,000 pounds per square inch, while the compressor, the storage reservoir and their connections operate under 2,000 pounds.

"The sketch shows a section of the joint. A groove of the section shown is turned in the face of each flange, a surplus or 'overflow' space being provided below. In the space formed by the grooves a strip of soft round rubber is inserted, the cross sections of the groove and rubber being so proportioned to each other that when the joint is closed the rubber will occupy part of the overflow space. The rubber used is not a continuous ring, but is cut from a long strip with a scarfed joint where the ends meet.

"It will be seen that the pressure coming down the joint drives the rubber into the angle at the top and that leakage is practically impossible. The grip of the bolts is not relied upon to retain the rubber by friction, as with the ordinary gasket. The joint is metal to metal, and the pipe sections may be gotten out to defined lengths—a feature that is occasionally useful. In the case of the gun, an additional feature of great value is that the tightening of the bolts does not, as with gaskets, tend to throw the sections out of line.

"As stated, this joint was used in a great number of cases, and I was assured that failure with it was unknown, positive tightness being expected and obtained as a matter of course."

MECHANICAL ENGINEERING AND SHIPBUILDING.

In his presidential address before the institution of Mechanical Engineers Sir William H. White, among other interesting points, drew a strong picture of the close relation which modern shipbuilding bears to mechanical engineering, showing how entirely the modern vessel, whether for war or for merchant service, is

the product of mechanical operations and mechanical skill. Says he: "Mechanical engineering has intimate relations with all other branches of engineering. With none has it been more closely associated than with shipbuilding in recent times, and upon none has its influence been greater or more beneficial. The growth of our shipbuilding industry and the marvelous development of our mercantile marine during the last forty years are matters of common knowledge. The causes which have contributed to this supremacy are not so well understood and the part which mechanical engineering has played is not generally appreciated."

After enumerating the statistics of the growth of British shipping during the period indicated, and dwelling upon the changes wrought by the substitution of iron for wood and steel for iron, Sir William shows the contrast between an old-time shipyard and one fitted out with modern mechanical appliances.

"The contrast between former conditions and those now to be seen in a modern shipyard is extreme. Machinery and labor-saving appliances abound and are essential and economical. With ships of increased dimensions scantlings have become heavier, the sizes and weights of plates and bars have increased, special arrangements have to be made for transporting and handling materials, and the power of all classes of machinery has had to be increased proportionally. In a well-equipped yard the most careful consideration is given to every step necessary in dealing with materials, from their delivery up to the time when they find their places in the structures of ships. The stacks of plates and bars are so situated that the materials can readily be lifted from the trucks on arrival, or out of the depot when required for use."

The general use of traveling cranes and gantries is a matter of note, and the increasing employment of hydraulic and pneumatic tools, both for stationary and portable service, is also important. It is in the combination of all the multitudinous variety of machines and tools that the great influence of the mechanical engineer upon modern shipbuilding is seen, and it is not only the

work of the mechanical engineer but also that of the electrician which has been utilized to the utmost.

"Electric power is being extensively used in some of the best equipped shipyards, apparently with satisfactory results. It is probable that the system will be much more extensively employed before long. For large machines with separate motors, and for groups of smaller machines, electric driving has much to recommend it. For operations that have to be performed *in situ* portable electric machines are found most useful. In some cases, especially in elaborately fitted warships, it is found advantageous to establish on board temporary machine shops, which can be most conveniently driven by electric power."

When it comes to the preparation of the material used by the shipbuilder the influence of the mechanical engineer predominates still more. Modern shipbuilding could not exist without the great progress which has been made in the manufacture of structural material.

"The shipbuilder is under great obligations to the steel maker for this progress in manufacture; but the mechanical engineer has had a hand in its achievement by designing and making the plant used in the steel works. In the device of new and more powerful machines for the shipyard his work has been more obvious. Without such machines the superior working qualities of steel could not have been utilized as is now done. Operations are now commonly performed on steel plates in a cold state that were not possible with the best qualities of iron."

In fact, all the long list of shipyard tools, including flanging, joggling, shearing and punching machines, as well as bending rolls, plate planers and all the better known machine tools are contributions of the mechanical engineer to the work of the shipbuilder.

On board the completed ship the work of the mechanical engineer is everywhere in evidence, from the propelling machinery, through the hoisting, lighting, ventilating and steering machinery down to the smallest and pettiest applications of power. On warships especially is the work of the engineer conspicuous, so

much so that the modern warship is not inappropriately called a "fighting machine."

STRENGTH OF BOILERS.

The annual reports of the engineers to the great boiler and engine insurance corporations invariably provide matter well worthy of study. The reporters have opportunities of obtaining information as to the merits of different designs which no one in other positions, no matter how great their practice or experience, is able to command. It is a trite saying that failure teaches more quickly than success, and the instruction is certainly based on safer premises, since the margin of safety in a machine or structure which escapes failure is often uncertain. Bridges, for instance, have, under test, shown absolutely no sign of weakness when loaded with 90 per cent. of the weight which ultimately destroyed them, and the unreliability of the hydraulic test of a boiler taken *per se* is, or rather should be, a commonplace. That this fact is still not as generally recognized as is necessary, is unfortunately proved only too well by the evidence given in certain of the Board of Trade inquiries. That this test should be so untrustworthy is highly inconvenient; as, were matters otherwise, boiler inspection—now a particularly disagreeable job—would be both simplified and made more attractive. Still, as matters stand, successful resistance to such a test is no guarantee that the structure is not in a dangerous condition; and, similarly, in the daily working of an engine or boiler good fortune may for long mask the existence of an unsuspected weak point, which will be discovered only when the actual breakdown takes place.

In the nature of things, inspecting and insurance associations are mainly concerned in the morbid anatomy of the engines and boilers covered by their guarantee, and thus for one breakdown that comes under the notice of an ordinary manufacturing or consulting engineer, a dozen or more will be carefully investigated by the officers of such a corporation.

The former class, therefore, will always find much worthy of consideration in the annual reports of the latter, and the report

just issued by Mr. Stromeyer, chief engineer to the Manchester Steam Users' Association, is no exception to the rule. In this report, Mr. Stromeyer has discussed at considerable length the collapsing pressure of flues, and has collected together particulars of many tests and of many failures. An empirical formula has also been devised by him, which fits these data fairly well. The formula is as follows:

Mean stress on plate at collapse, in tons per square inch =

$$3 + \frac{169{,}000}{13{,}000 + \left(\frac{L}{t}\right)^2}$$

where L represents the length of the flue and t the thickness, both in inches. With very short flues this formula gives the stress at collapse as 16 tons per square inch, whilst for very long ones the stress becomes 3 tons per square inch. Being an empirical formula, it should not, of course, be used outside of the special circumstances it has been designed to fit. Indeed, exception may justly be taken to the formula in that the stress at collapse is made to depend solely on the length and thickness of the flue, and not at all on its diameter. Thus, a tube 30 feet long, 1 foot in diameter, and $\frac{1}{4}$ inch thick would certainly carry a greater stress per square inch before collapse than one 3 feet in diameter, but of the same length and thickness. A ring near the middle of such a tube is exposed to a uniform compression, and thus closely resembles a column, and will finally yield by collapse in quite a similar way. The effective length of this virtual column is greater the greater the diameter of the flue, and the stress at collapse is correspondingly less for tubes of large diameter than of small, the thickness of the plate remaining constant.

The effect of stiffening rings and the like in increasing the collapsing pressure is of an indirect nature; and, in fact, it can easily be shown that within the elastic limit the action of such rings is actually to increase the maximum stress in the material of the flue. Professor Unwin has, however, pointed out that when a very long tube collapses, such tube, after deformation, has four points of contrary flexure, and hence the length of the virtual columns into which the tube separates is a quarter the

total circumference. With shorter tubes the collapsed section exhibits more points of contrary flexure, thus shortening the length of the virtual columns, and consequently increasing the stress at which failure finally occurs.

For these reasons, therefore, Mr. Stromeyer's rule will require careful consideration before it can be accepted as of universal applicability, although it seems to accord extremely well with the results of experiments made here and abroad, the more especially when it is borne in mind that small geometrical errors of form or small local variations in the elastic properties of the material used may, in such experiments, have a disproportionate effect on the results.

ATOMIC WEIGHTS.

With the recent production by Professor Richards of a new table of the atomic weights of the seventy-four elements, the question of a revised international standard table is once more agitated.

At present there are at least seven tables of atomic weights in general use, namely, the governmental, compiled by Mr. Clarke; the more recent tabulated results of Professor Richards, of Harvard University, and the well-known standard weights of Berlin, Meyer, Scubert, Ostwald and Van der Plaats. As there are no two of these tables alike, much clamor arises because of discrepancies resulting when any two of these tables are consulted for reference.

A practical illustration of this occurs in the importation of chrome iron ore from Europe. In Europe the general atomic weight taken for chromium is 52.5, based on the ancient work of Berlin, a table used by many of the European analysts. In this country the more recent table of Mr. Clarke is the authority. This one takes 52.1 as the atomic weight of chromium. Thus a discrepancy of $367.50 on a cargo of 2,500 tons of this ore occurs when it is assayed in Glasgow and then again in the United States. Should the still more recent results of Professor Richards be taken, namely, 52.14, the variation would be but $330.95 on a cargo. Thus it is seen that even the apparently slight dif-

ference of four parts in a hundred, which for practical purposes would seem unimportant, causes a loss or gain, either way you wish, of $36.55 on a single cargo. Of what enormous value to dealers would be a standard international table of atomic weights, whereby each cargo would have the same relative value whether assayed in Europe or America.

The labor involved and the accuracy and skill required to compile a table of atomic weights is very great, so difficult that even some of the best of chemists refuse to spend their time and risk their reputation in performing this task.

The stupendousness of the work can be slightly conceived when one realizes the minuteness of an atom. The atom is defined as the smallest particle of matter, and is believed to be incapable of division into parts. These particles are so small that they cannot be observed even under the most powerful of microscopes, and so solid that they cannot possibly be broken or abraded by any concussion or violence whatsoever. To each of these atoms, however, a certain so-called atomic weight has been assigned; that is, a relative weight of the atoms, or the proportions in which they unite.

Certain of the well-known tables are constructed on the assumption that the atomic weight of hydrogen is 1. With this as a basis, the atomic weight of oxygen is determined as slightly more than 16. Others assume the atomic weight of oxygen to be 16, and in a table constructed on this basis the atomic weight of hydrogen is found to be slightly less than 1. Thus these two tables will vary slightly in all of the determinations.

This fact, however, is not the only cause for discrepancy in the different standard tables; indeed, it is probably the cause of only the slighest variation.

The principal errors in the determinations result from imperfect mechanical separation, crystallization and ignition, due to the partial solubility of nearly all precipitates and containing vessels, and also to the occlusion of foreign matter in crystals, oxides and other substances. Although these errors are carefully weighed and considered and allowances are made for them, it nevertheless stands to reason that as all of the tables are en-

tirely independent of one another, or nearly so, there will still be discrepancies between them.

Name.	*Symbol.*	*At. Wgt.*
*Aluminium,	Al.	27.1
Antimony,	Sb.	120.0
Argon,	A.	39.9
Arsenic,	As.	75.0
Barium,	Ba.	137.43
Beryllium,	Be = Gl.	9.1
Bismuth,	Bi.	208.0
Boron,	B.	10.95
Bromine,	Br.	79.955
Cadinium,	Cd.	12.3
Caesium,	Cs.	32.9
Calcium,	Ca.	40.0
Carbon,	C.	12.001
Cerium,	Ce.	140.0
Chlorine,	Cl.	35.455
Chromium	Cr.	52.14
Cobalt,	Co.	59.0
Columbium,	Cb = Nb.	94.0
Copper,	Cu.	63.60
Didyium,	Nd + Pr.	142.0
Erbium,	Er.	166.0
Fluorine,	F.	19.05
Gadolinium,	Gd.	156.0
Gallium,	Ga.	70.0
Germanium,	Ge.	72.5
Glucinium,	Gl = Be.	9.1
Gold,	Au.	194.3
Helium,	He.	4.0
Hydrogen,	H.	1.0075
Indium,	In.	114.0
Iodine,	I.	126.85
Iridium,	Ir.	193.0
Iron,	Fe.	56.0
Lanthanum,	La.	138.5
Lead,	Pb.	206.92
Lithium,	Li.	7.03
Magnesium,	Mg.	24.36
Manganese,	Mn.	55.02
Mercury,	Hg.	200.0
Molyddenum,	Mo.	96.0
Neodymium,	Nd.	143.0
Nickel,	Ni.	58.20
Niobium,	Nb = Cb.	94.0
Nitrogen,	N.	14.045
Osmium,	Os.	100.8
Oxygen (standard),	O.	16.0
Palladium,	Pd.	106.5
Phosphorous,	P.	31.0
Platinum,	Pt.	195.2
Potassium,	K.	39.140
Praseodymium,	Pr.	140.5
Rhodium,	Rh.	103.0
Rubidium,	Rb.	85.44
Ruthenium,	Ru.	101.7
Somarium,	Sm.	150.0
Scandium,	Sc.	44.0
Silicon,	Si.	28.4
Sodium,	Na.	23.0
Sulphur,	S.	32.065
Selenium,	Se.	79.0
Silver,	Ag.	107.93
Strontium,	Sr.	87.68
Tantalium,	Ta.	183.0
Tellurium,	Te.	127.5
Terbium,	Tb.	160.0
Thallium,	Tl.	204.15
Thorium,	Th.	233.0
Thulium,	Tu.	170.0
Tin,	Tn.	119.0
Titanium,	Ti.	48.17
Tungsten,	W.	184.4
Uranium,	U.	240.0
Vandlium,	V.	51.4
Ytterbium,	Yb.	173.0
Yttrium,	Yt.	89.0
Zinc,	Zn.	65.40
Zirconium,	Zr.	90.5

* "A New Table of the Atomic Weights of the Seventy-four Elements." Presented before the American Society of Arts and Sciences, March 9th, 1898, and published in the "American Chemical Journal" of July, 1898. Complied from the most recent data by Prof. Theodore W. Richards, of the Chemical Laboratory of Harvard University.

In the above table compiled by Professor Richards, all of these facts have received due consideration and allowances have been made for them. Chemical and mathematical errors have been eliminated so far as possible, and in every way he has striven to make the table as accurate and complete as possible, but at the same time practical. Neither has this table been compiled independent of the other standard tables. In each determination comparison has been made with the best. In some cases, such as those of the rarer metals, where sufficient data could not be obtained to insure the correctness of the one or the falsity of the other, a compromise has been made, and the mean between the two decided upon.

In a comparison between Mr. Clarke's and Professor Richards' tables, the results are seen to agree very closely. Only in about seven determinations is there found any appreciable discrepancy. In these cases, namely, the weights of antimony, cadmium, calcium, magnesium, platinum, tungsten and uranium, however, the new figures of Professor Richards find preference, first, perhaps, because of the more recent methods and improved determinative processes used, and, secondly, because of his reputation as a chemist and metallurgist. As these tables are to-day used by chemists and metallurgists in every assay and analysis the discrepancies between them, especially between the seven elements mentioned, are of no little importance.

To have one, and only one, standard international table compiled by a committee composed of the eminent chemists of the world, would be hailed by all kinds of chemists and dealers alike, as an epoch in the history of chemistry. Means, appliances, the best of specimens and the more recent data would be at their disposal, and, together with the accuracy and skill of the committee themselves, should result in the production of a table that would be far more accurate than any yet produced. It would undoubtedly meet with universal approval and would eliminate the present confusion, caused by the numerous so-called "standard" tables on the market to-day.—W. H. Swenarton, in "Yale Scientific Monthly."

NEW SYSTEM OF FORCED DRAFT.

[Extract from a paper by Mr. Nelson Foley, read at a recent meeting of the Institution of Naval Architects.]

The writer has called the system about to be described new, believing it to be original and, up to the present, untried, except by himself; but he is naturally open to correction, should such not prove to be the case. The fundamental principle of the system is that the fire bars themselves are utilized as a means of forcing the air into the fire. In order to accomplish this, these bars are made hollow, and are perforated with a row of small holes along each side near the upper surface, the holes being placed at such an angle that the air is forced in jets into the fire through the ordinary spaces between the bars. The front ends of the bars are inserted into a box or canal under the fire door, which is in communication with a fan.

Without being sanguine of a satisfactory result, it was thought that the benefits to be gained in leaving both stokeholds and ash-pits open were sufficient to justify some experiments being made on a small stationary water-tube boiler. The results have been so far beyond expectation that the subject appears to the writer to be of sufficient interest and importance to warrant his bringing it under the notice of the Institution; in fact, it seems to him to bid fair to cause some revolution in forced combustion. The results of these experiments are appended at the end of the paper.

Up to the present only short bars have been experimented with, but a sample bar up to 4 feet in length has been cast without difficulty; at the same time, where it is possible to have an air box at each end of the grate, the bars need never exceed the moderate length of, say, 3 feet. A method of uniting them in the center has always been devised for such cases as when the front only is available for an air box and a long grate is desired. It should be noted, however, that it is thought preferable, in order to give facilities for good stoking, cleaning fires and keeping the fires in good order, to work always with short grates and use a high rate of combustion. It has been observed during the experiments that little refuse falls into the ash pits, that the bars keep perfectly cool and that the clinker does not adhere to

them; in fact, from time to time the clinker can be removed from the fire without drawing the same. It has also been noticed that during forced draft the bars do not suffer at all, although it is only fair to say that on one occasion the ends of some of the bars were burnt because the bridge at the back was not in order, a space being left between it and the bar ends. The bars have been tried at natural draft, and after ten days' continual steaming during day hours, no more than the normal injury was sustained, and only a few holes were found choked.

It is intended, in adopting this system, that the full advantage should be taken, making the grates moderate in length, and running with forced combustion as a normal condition. In this matter the destruction of fire bars would be reduced to a minimum, and the fires could be regulated to a nicety. The fire can be regulated also, so that it is a matter of indifference whether the fire door is open or shut; but, of course, it cannot be overlooked that, at very high rates of combustion, especially with ordinary cylindrical boilers, the fire door must be kept shut, as with the ordinary ash pit draft. Presuming a long life for the individual bars, the cost of production need not, it seems to the writer, be considered a serious matter; for the foundry in Naples it comes to about 10 centimes per kilogramme.

RESULTS OF FORCED-DRAFT EXPERIMENTS.

Experiment.	Air pressure.	Coal, lbs. per hour per sq. ft. of grate.	Jet holes.		Bars.		Observations.
			Diam.	Pitch.	Length.	Surface.	
	ins.		*in.*	*in.*	*ft. in.*	*sq. ft.*	
1	1.38	29	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
2	1.45	32	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
3	1.25	41	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	For combustion only.
4	1.73	40	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
5	3.15	72	$\frac{3}{16}$	$\frac{11}{16}$	1–3½	3.22	For combustion only.
6*	3.15	53	$\frac{5}{16}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.

* During this trial it was thought that for this rate of combustion the passages to the funnel were too contracted. On measuring the same they were found to be collectively between one-sixth and one-seventh of the grate area, whereas the funnel area itself was one-fifth.

The experimental grate was 2 feet 7½ inches long and 2 feet 7½ inches wide; in the case of experiment No. 5, however, half

the length was bricked over. The air pressure was obtained from a smithy blast, the strength of which was never more than 80 millimeters ($3\frac{1}{5}$ inches). Coal was of the Cardiff kind, of good quality. Height of funnel from bar level, 17 feet 6 inches.

POWER REQUIRED BY MACHINE TOOLS.

In determining the power consumed by machine tools when operating under various conditions it is customary to measure the power required when running empty and deduct this quantity from that used when performing work. That this method is not exactly correct has long been known, since it it evident that the friction of the machine itself cannot be the same in the two cases, but it has been assumed that the error from this cause was not great enough to be of material consequence.

In the course of a recent series of experiments to investigate the power consumed by metal-working tools, MM. Huillier and Fremont made an interesting calibration of the dynamometer used, in connection with various determinate degrees of resistance at the machine, and thus were enabled to take the increased friction of the tool into account. A very full report of these valuable trials upon a number of tools is given in the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," the whole forming an important contribution to this branch of technical knowledge. The variations in frictional resistance were made by delivering the power of the tool, a lathe for example, through a recording dynamometer of the Morin type, while various resistances were opposed by means of a Prony brake acting upon a pulley on a mandrel turned by the lathe. If the frictional resistance of the lathe had remained constant, the differences between the brake and dynamometer readings should have continued uniform, while any variations between the two measurements indicated the variation in the resistance of the lathe. By plotting the results of a number of such tests it was demonstrated that the friction of the machine increased directly with the resistance, being, in the case of a large lathe tested, equal to 16 per cent. of the added resistance on the brake. This

coefficient of 16 per cent. varied somewhat according to conditions of lubrication, temperature, etc., and similar coefficients should be determined for different groups of machines before making extended tests.

In conducting their further trials upon the resistance of machine tools, MM. Huillier and Fremont adopted the method of measuring by the dynamometer the amount of power delivered to the machine and taking the effective work from the pressure exerted at the cutting point of the tool. In order to measure the actual pressure at the tool, an ingenious form of dog was devised, of which detailed illustrations are given in the original paper. In the usual method of working the dog is clamped firmly to the work to be revolved in the lathe, and is also engaged positively with the face plate, the work being thus pushed around by the force applied to the plate. In these experiments, however, the dog is so arranged that it is pulled around instead of being pushed, and, being connected to the work by a spring arm, the effort required to revolve the piece against the fixed resistance of the cut is measured by the deflection of the spring. An ingenious system of levers transmits the deflection of the spring, as it revolves, to a fixed recording card, and, the leverage being known, the resistance of the tool at the cutting point is recorded continuously. When to this is added a simultaneous record of the speed of the surface upon which the cut is acting, all the data for the computation of the power exerted are determined. Another factor, which although not essential to the measurement of the power is of interest in connection with machine design, is the direct pressure required behind the tool for a given depth of cut. This was determined by a special pressure device fixed upon the slide rest.

Before proceeding to the use of these devices they were carefully calibrated by the direct application of weights, and the proper factor determined, so that reliance might be placed upon the corrected readings, the deflections only being measured and the corresponding pressure computed.

In the application of these devices some interesting observations were made. During a continuous cut, as in the turning of a

shaft, for instance, the resistance was by no means uniform, varying in the case of a shaft 92 millimeters in diameter, from 270 to 337 kilogrammes. This variation may be attributed to two causes: the lack of homogeneity in the metal and the breaking of the turnings. The unequal hardness of the material was evident, and it was easy to observe that variations in pressure on the tool occurred periodically as certain portions of the shaft came under the tool; the breaking of the turning could also be seen to affect the record of resistance. Making allowance for these variations, by taking the mean resistance for a continuous run and weighing the quantity of metal removed in the form of chips and turnings, a very complete record of the performance of various tools was obtained and tabulated.

In the paper above referred to the effort was made to determine more especially the power required by the various machines, and hence the conditions of the cutting tools themselves was maintained as nearly constant as possible, but in subsequent researches it is intended to vary the cutting angles, depth of cut, and similar conditions, and thus make practical comparisons. The present paper contains data from twenty-one different machine tools, giving for each machine the following data: speed of belt, pull on belt, power delivered, speed at the cutting point, weight of chips produced per hour, and net amount of work required to produce one kilogramme of chips, the tools including a variety of lathes, milling machines and drill presses.

THE BOOM IN STEEL AND IRON.

There is no doubt that the principal cause of anxiety among those who have studied the conditions of the present era of prosperity in the United States is as to the ability of obtaining an adequate supply of steel and iron, which lie at the very basis of industrial activity in the present age, and emphatically so in the line of shipbuilding. When we read that although the production of iron and steel is the largest on record, that the importation of iron ore is also exceeding the record, but still inadequate to the demand in spite of the increased output of

native ores also, and that Germany is coming to us to buy pig iron, it can readily be seen that the situation is not only unique, but a cause for apprehension. While Pennsylvania plants are obliged to work to their fullest capacity to fill the orders already booked, word comes from Alabama that furnace men at Birmingham are canceling orders for pig iron because there is no product to supply the demand. It is stated that orders enough will be placed within six months to keep furnaces busy all next year. Meantime in some shipyards keels are laid for which it is impossible to get iron or steel to make headway in construction, and some builders are in consequence declining to agree to any time limit as to further contracts.

The record of pig iron output shows that the largest tonnage in the history of the United States was produced during July, the estimated weekly output having been 269,032 gross tons per week, which was an increase of 12,154 tons per week over the output of June, and that month had 1,689 tons per week of a greater output than any previous similar period. Nevertheless the demand increases faster than the ability to produce. Some furnaces will not take orders for next year yet, and prices for delivery during the first half of 1900 are quoted by only a limited number of producers. The fact that our last year's product exceeded by ten per cent. our previous maximum and is already far in advance of the output of Great Britain, adds to the peculiarity of the position.

The outlook for the industry is one dependent in great degree upon the careful management of those in charge of the great fundamental businesses for continued success. If there are no strikes, and if other nations do not overtake us, as there seems no probability of any of them doing, the United States will lead the world next year in this most important line of activity. Besides the demand abroad for our finished products of steel, such as bridges, rails, railway materials, machinery, etc., which our contractors must fill, our shipyards must be supplied with the necessary steel to keep their plants going, and these must become prior demands upon steel manufacturers. If smooth working in all the contiguous lines of this industry continue,

therefore, our nation is certainly booked for a long continuance of unparalleled prosperity.—Ex.

THERMODYNAMIC ACTION OF "STEAM GAS"

One of the most valuable papers recently published in the field of applied sciences is that which has been just reprinted from the "Revue de Mécanique" of the last year, the work of Professor Sinigaglia, of l'École des Ingénieurs de Naples, a well-known author in the field.

This is the latest and, in many respects, the most complete discussion of a supremely important subject, one to which the minds of men of science and engineers the world over are now again turning after a period of many years, during which thermodynamic promise of gain in efficiency in the steam engine through the conversion of a vapor into a gas by this process of superheating had been almost universally believed to be more than counterbalanced by the very serious difficulties met in the earlier days in the attempt to profit by it. Changes have taken place during the last generation which are now thought by many authorities to have largely reduced the obstructions formerly seemingly fatal to the great thermodynamic advance.

In the practical thermodynamic operation of the steam engine, as M. Bertrand has remarked, there is no such thing as "saturated vapor," as that term is customarily employed by the thermodynamists. The working fluid is always, in fact, a mixture of vapor and its liquid in a state of instability as to quality. The investigations of the "*théorie générique*" made by Rankine Clausius, Zeuner and others resulted in establishment of no rational expressions for the actual heat exchange of the real, as distinguished from the ideal, engine, and Hirn's "*théorie expérimentale*," as developed by that great investigator and his disciples, is still the only resort of the student of the curious extrathermodynamic processes accompanying the thermodynamic operation of the engine.

Supherheating has come to be looked upon, not as a method of giving superior thermodynamic action, but as simply a pro-

vision for reducing internal wastes due to heat exchanges between the steam and the metal surrounding it. Its effectiveness was recognized as early as Trevethick's time (1828 or earlier), and became well understood about the middle of the century; since which time numerous inventions have been made looking to its utilization, few giving any promise of success. The Alsatian school has revealed very completely the method and the effect of its adoption, and it has come to be well understood that its province is simply to reduce that form of waste known as "initial condensation" or "cylinder condensation." Its successful use would affect the suppression of those losses in such manner, in the words of Dwelshauvers-Dery, as to give maximum efficiency by securing the exhaust of the steam from the engine in the dry and saturated condition. This is, in his opinion, the practical criterion of most perfect action. The actual gain has been found by Hirn to be, in several cases studied by him experimentally, from 20 to nearly 50 per cent., with a superheat amounting to from 210 degrees centigrade to 245 degrees centigrade. The nearest approximation yet reported to the ideal, purely thermodynamic case has been affected by this means—particularly of late by Schmidt.

The failures of the past have been due to difficulties in securing an apparatus which cannot be rapidly injured by excess of heat, in presence of superheated vapor of water, and a system of lubrication of the cylinder and piston capable of working satisfactorily at the temperatures attained in effective superheating. The latter obstacle is now overcome, largely by use of the high-test mineral oils; the former remains a serious obstruction. The increasing steam pressures of our day also reduce both the need and the availability of increasing superheat.

The results of successful superheating exhibit themselves both at the engine and at the boiler, and, as with multiple-cylinder engines, the gain at the boiler in economical employment of fuel is greater than that at the engine through a more perfect thermodynamic action; for the reduction of the demand for steam at the engine results in an increased economy in the production of such steam through the larger proportion of heating

surface to weight of steam produced. Thus a gain of 20 per cent. at the engine may be accompanied by a gain of 22 per cent. or more in fuel as measured at the boiler. The desirable amount of superheat is that which will prevent the condensation of the vapor entering the steam cylinder and insure its rejection as saturated vapor at exhaust.

The apparatus employed by various inventors and investigators in this field, from 1850 to our own time, is described at considerable length by M. Sinigaglia, and the results of experiment are recited. In many instances, recently, particularly, it is reported that no serious inconveniences were met with in the application of this system; in other cases much trouble and sometimes serious accidents resulted, due to the "burning" of the apparatus and its yielding, thus weakened, to the pressure. Messrs. Ludwig and Weber obtained, in an extensive series of experiments in Alsace, some very encouraging figures. An average gain of 7.5 per cent., net, was secured by moderate superheat (44 degrees centigrade). Messrs. Walther-Meunier, and Ludwig later, reported a gain of 13 to 15 per cent. from a superheat of somewhat greater amount. Schwoerer obtained a gain in efficiency of 15 to 18 per cent. by superheating 68 degrees centigrade. Hirsh reports similar figures from an equal amount of gasification in a marine apparatus. Schroeter obtained gains of 10 per cent. and more in a very elaborate and detailed investigation, in which the superheat amounted to 60 degrees centigrade. The most remarkable results reported are those of Schmidt, who, by adopting an enormous proportion of superheating to heating surface (six to one), secured a superheat of 190 degrees centigrade, and at another time, with a comparatively small apparatus, secured the highest record yet established. With another engine a gain in weight of steam supplied the engine, amounting to nearly 40 per cent., was effected, and in weight of fuel, 28 per cent.; the difference being due, obviously, to the fact that each unit weight of steam carried an abnormal quantity of stored heat.

Professor Sinigaglia concludes:

1. Superheating vapor is proved irrefutably to be the most

effective system of reduction of internal wastes of heat in the steam engine.

2. The higher the degree of superheating attainable, the nearer does the thermodynamic result approximate that indicated by pure theory and by the formulas of thermodynamics.

3. From the industrial point of view, it is necessary to note the gain, not at the engine, but in fuel demanded at the boiler, and the apparatus of vaporization and of gasification must be efficient and durable.

4. The final test is in the study of the financial aspect of the operation.

"But, to-day, the numerous installations in Alsace and Germany have given such remarkable results that the end will be that they will overcome the last difficulties which oppose a general application of superheating to steamships. This will be the best homage paid to Hirn and his school."—R. H. Thurston, in "The Sibley Journal of Engineering."

NOMINAL EFFICIENCIES OF MACHINERY.

Without straining after the sensational by purloining upon the precincts of the impossible, it suffices to direct attention to the enormous wastefulness of the processes upon which we are dependent at the present day for the great bulk of our useful mechanical power. Nearly all of this power is developed in steam engines, and these, although marvels of ingenuity, are exceedingly wasteful means of transforming chemical into mechanical energy. The efficiency of boilers is fairly good, being not unfrequently 80 per cent.; but the efficiency of the best engines scarcely exceeds 20 per cent., and, in fact, this efficiency is only reached in comparatively rare instances. The combined efficiency of engine and boiler, with reference to the heat energy in the coal, is, therefore, rarely as high as 16 per cent. Strictly speaking, of course, the best engines should not be regarded as wasting 80 per cent. of the power they receive, since an ideally perfect heat engine would, under the same conditions, only be

capable of utilizing about 35 per cent., so that the efficiency of the best engines is nearly 60 per cent. with reference to the behavior of ideal heat engines working between the same limits of temperature. When we consider, however, that engines in common practice give results considerably below these figures, and commonly deliver only about 5 per cent. of the energy resident in the coal they burn, it is evident that enormous room for improvement exists in the direction of transformation of energy.

The efficiency of refrigerating machines is practically the only efficiency which is commonly stated as being in excess of unity, or 100 per cent., and is, therefore, an apparent exception to the general rule that an efficiency may not be greater, and is usually appreciably less, than 100 per cent. In some cases the efficiency of an ammonia refrigerator expressed as the ratio of the heat energy withdrawn from the refrigerating room to the mechanical energy expended by the compressor in the process is over 4, i. e., over 400 per cent. This high nominal efficiency has sometimes led to the erroneous belief that refrigerating plants were capable of practically creating energy. The reason for this high nominal efficiency of the refrigerator lies in the fact that under acknowledged thermodynamic law some four units of heat energy have to be transferred from a furnace at the temperature of 100 degrees centigrade to the cooling chamber at a temperature of 7 degrees centigrade, in order to liberate 1 unit of mechanical energy in a perfect engine working between the two. In other words, the theoretical efficiency of the engine would be only about one-fourth, or 25 per cent. But all perfect heat engines are reversible. It therefore follows that if the operation of such an engine were reversed each unit of mechanical energy supplied to the engine would bring about the transfer of 4 units of heat energy from the cold chamber to the hot chamber, or the efficiency of the process would be 400 per cent. But, of course, this high efficiency is of no practical value in the production of mechanical power, since on again reversing the engine it would take 4 such units of heat energy to give out 1 unit of mechanical work. This use of the word efficiency in regard to refrigerators, unless carefully defined, is unfortunate.—"Electrical World."

FLANGING HEAT FOR STEEL PLATES.

The importance of the working of boiler sheets in flanging at temperatures above the "blue heat" does not appear to be generally appreciated, although it has been known for years that steel worked too cold receives permanent injury which is likely to cause it to fail under stresses that are far below its normal strength. This was one of many valuable points brought up for discussion by Professor Hibbard's paper on locomotive boilers, recently read before the New York Railroad Club, and it will pay those who make or repair boilers of any type to examine their practice in this regard. Flanging is a difficult operation, especially when performed by hand without the aid of special formers. The work is naturally slow and the tendency to use as few heats as possible is strong. The result of this is to work the sheets as long as possible after each heat, and frequently the temperature falls until the metal receives permanent injury, even before it has been put in place in the boiler. The ideal method of forming and flanging boiler plates is to use large furnaces, heating the entire sheet at once, and then, by the use of hydraulic presses and dies, to press the sheet into the desired form at a single operation. This, of course, requires a large outlay for special machinery and dies, which small establishments cannot afford. The smaller sectional hydraulic flanging presses are available, however, and large dies are not needed with these. The work is not as rapid as with the large presses and the danger of working at the blue heat is greater. A satisfactory rule for judging of the temperature below which the work should not be done is to rub a piece of wood over the surface of the plate, and if it does not leave a red glowing path the sheet is too cold and the work should stop. The necessity for increased care in this connection is more apparent with the increase in steam pressures, and by insisting upon this simple rule in the boiler shop a great deal of anxiety may be avoided. The "blue heat" occurs between temperatures of 550 and 700 degrees and is below the temperature at which iron will show a red glow in the dark. Its most prominent effect seems to be to reduce the ability of steel to resist repeated bendings, and the life of

modern locomotive boilers depends very largely upon this quality. A sheet which has undergone this treatment will withstand only about one-third as many bendings as before.—"American Engineer and Railroad Journal."

POSSIBILITIES OF THE TURBINE.

A subject of general interest in the field of marine engineering just now is the derivation of power for vessel propulsion from steam turbines. Discussion of this force heretofore presented has been open to doubt, not only on the score of authenticity of the assertions made, but also from question as to the reliability of the source of information. Especial value therefore attaches to an article on the subject in the current issue of "Cassier's Magazine" by Hon. C. A. Parsons, of England, inventor of the type of turbine bearing his name, and the builder of the *Turbinia*, the first vessel to which this force was applied.

Mr. Parsons deals at the outset with the first problem which presented itself to him, that of constructing a steam turbine of good steam economy and with a comparatively moderate speed of revolution, so as to permit of its being coupled directly to a dynamo. Some of the advantages claimed for steam turbines over ordinary engines are the small space occupied, light weight, low first cost, reduced upkeep and attendance, better governing, together with the fact that no expensive engine foundations are required. Mr. Parsons is emphatic in the declaration that the most important field for the steam turbine is in the propulsion of ships, by reason of the imperative necessity for some form of engine which shall be light, capable of perfect balancing and economical in steam. The disappointments which followed the construction of the *Turbinia* will be full of interest for marine engineers generally. They were induced, of course, by the speed, which was so much slower than had been anticipated as to make it apparent that there was some radical defect in the propellers. How it was discovered that there was an insufficiency of blade area, or that, in other words, the water was torn into cavities behind the blades—cavities which contained no air

but only vapor of water—has heretofore been detailed. On the obviation of all vibration so pronounced in all other fast vessels, however, Mr. Parsons lays considerable stress. The economy of engines is also demonstrated, he says, by actual figures, the consumption of steam per indicated horsepower for all purposes at 31 knots speed being given as 14½ pounds, or, in other words, with a good marine boiler the coal consumption would be considerably under 2 pounds per indicated horsepower. At a recent trial to test the endurance of the machinery it was demonstrated that the *Turbinia* can maintain a speed of 30 knots for three hours.

The information is given that each of the torpedo-boat destroyers of the *Turbinia* kind building for the British Government, and which have been previously referred to in the "Review," will be fitted with turbine engines of 12,000 horsepower. In the case of these vessels, as with the *Turbinia*, the great claim is relative to the saving of weight, the horsepower per ton of total weight of machinery including boilers in working trim being in the case of the new turbine-equipped vessels 75 as compared with 48 in the case of ordinary engines. Although the claim is made that the turbine engine offers many advantages to the naval architects of Atlantic liners, it is admitted that the highest speeds will be attained by short-passage vessels.

Perhaps the most interesting feature of Mr. Parson's article is his final observation. He says: "In conclusion it may be interesting to give a few particulars as to what may ultimately be reached in fast-speed, unarmored cruisers of moderate size, though doubtless it will take some courage to enter upon the construction of such a vessel. Still, something like this will probably be attempted before long: A vessel of 3,000 tons displacement, 450 feet in length, 42 feet beam and 14 feet maximum draught of water, carrying turbine engines and boilers of 120,000 maximum horsepower, the boilers being of the water-tube type arranged in two tiers. This vessel could steam economically at 16 knots speed, but would, in emergency, be capable of increasing her speed to 48 knots and maintaining this speed for three hours; or she could maintain a speed of 45

knots for eight hours. She would be difficult to hit with shot, and her speed being 18 knots greater than that of any locomotive torpedo, she could take her chance in this respect. A few such vessels would be of immense tactical value to a squadron in time of war."—" Marine Review."

MISCELLANEOUS.

GASOLINE ENGINES.—The remarkable progress which gas and gasoline engines are making is a natural result of education in regard to their advantages. The best of steam engines used for ordinary work consume about 2 pounds of coal per horsepower hour and from 6 to 12 pounds more nearly represents common practice with small steam engines. The cost of attendance for a steam plant is very high and proportionately higher per horsepower as the size of the engine decreases. A steam boiler requires constant nursing, frequent cleaning, scaling and overhauling, and also these expenses are constant, even if the engine is used but a few hours each day. The internal-combustion engine presents an agreeable contrast to all this. It starts easily and quickly, and when once started it needs only to be oiled and properly loaded to work along unattended all day long. The fuel consumption is proportional to the load, and when the engine stops all expense stops also. As to the relative cost of operation, it may be confidently accepted that a gasoline engine will cost not more than half as much to run as a steam engine of equal power. The time has come for the gas engine to receive careful consideration by all who contemplate enlarging or remodeling old shops, and especially by those who are planning new ones. The new Westinghouse works for the manufacture of air brakes in Russia are to be driven entirely by gas engines. Why should they not be used for driving the machinery of railroad shops? They offer a most satisfactory method of distributing power, and there are many designs that are quite ready for important responsibilities.—"American Engineer and Railroad Journal."

MOST INTENSE HEAT YET OBTAINED.—The heat of the electric furnace, which is due simply to an electric arc enclosed in a closed crucible of incombustible material, is the greatest that can be obtained artificially. When this was run up to about 6,300 degrees Fahrenheit by Professor Moisson it was thought that the limit had nearly been reached; but Professor Tucker, of Columbia University, has "beaten" the French professor by several hundred degrees, we are told by "Electricity." An interesting result is that whereas the artificial diamonds that could be made in Moisson's furnace—perhaps its most interesting products—were exceedingly small, much larger stones have been produced in the improved Tucker furnace. Says "Electricity": "Some time ago Professor Moisson, by means of a specially-devised electric furnace, succeeded in making artificial diamonds, the largest, however, not measuring much over forty-thousandths of an inch in diameter. The heat then generated, the most intense ever produced up to that time, was about 6,300 degrees Fahrenheit, whereas, if reports are to be credited, Professor Tucker succeeded recently in obtaining a heat of between 6,500 and 6,700 degrees.

The principal aim of the experiment was to determine the commercial value of the extreme heat obtainable from an electric arc, and with this object in view a special furnace was devised which is said to be an improvement over that made use of by Professor Moisson. Artificial diamonds were made by Professor Tucker in much the same manner as those made by Professor Moisson before a New York audience some three years ago, namely, by placing cast-iron chips in a plumbago crucible and covering them with carbon. The whole was then subjected to the full heat of the furnace, after which the crucible and its contents were withdrawn and plunged into icy water, the sudden contraction of the molten iron furnishing the necessary pressure for crystallizing the carbon. The experiment is said to have been very successful in that a diamond larger than any so far made was produced. Aside from this fact, the experiment was interesting as showing the enormous heat which may be produced by the electric furnace, probably the most intense yet ob-

tained, and which should ultimately be the means of reducing the cost of production of certain substances, such, for example, as calcium carbide, now in demand for commercial purposes."—"The Literary Digest."

THE SMOKE NUISANCE IN PARIS.—Notwithstanding the general impression that Paris is a notably clean city, the growth of the smoke nuisance has forced the municipal authorities to take measures for its regulation by legislation. Before proceeding to do this, however, they appointed, in 1894, a technical commission to investigate the subject. This body has lately completed its labors and has published a report embodying its results and recommendations, an abstract of which is herewith taken from "Engineering Magazine."

The commissioners instituted a series of tests with the view of determining what were the best attainable smoke-preventing devices, and offered prizes to the furnaces demonstrating the best results.

The outcome of this procedure was the entering for competition of no less than 110 smoke-preventing appliances, which may be classified as follows:

(1) Mechanical stoking and uniform combustion,	16
(2) Supplementary injection of hot or cold air,	20
(3) Injection of steam with or without addition of air,	5
(4) Mingling of flames and combustion of smoke,	7
(5) Gas producers and gas firing,	7
(6) Pulverizing the fuel previous to combustion,	2
(7) Washing of the discharge gases,	16
(8) Miscellaneous systems,	37

The following information relates to the manner of making the tests:

"The various devices were successively erected under the same boiler * * * and the same fuel was used in all the tests. The fuel was the Anzin briquette, of the ordinary quality, containing an average of 8.17 per cent. of ash and 17.84 per

cent. of volatile matter. Each device was subjected to two kinds of tests, one with slow firing, and the other with the firing forced to supply the engines fed by the boiler to their full capacity. Each test was made twice, the first time with a stoker selected by the maker of the device, and the second with the stoker employed by the commission, thus eliminating as much as possible the personal equation. * * * The tests included the determination of the quantity of fuel burned per unit of grate area, and the evaporation per unit of area of heating surface and per unit of weight of fuel, as well as the measurement of the relative amount of smoke produced.

"The measurement of the amount of smoke produced by each device was accomplished by an ingenious method, which, while probably hardly entitled to be considered as a method of precision, was still reasonably correct, and doubtless fair to all the devices tested.

"A smoke scale of five degrees of intensity, ranging from complete absence (of smoke) to complete opacity, was decided upon, and the amount produced was recorded upon cylinders revolved by clockwork, by means of a pencil which could be pressed into contact with the paper by hand. The observer, watching the chimney top, pressed the pencil against the paper during any period when smoke was produced, the paper being divided into five portions corresponding to the five grades of smoke."

So much for the method of the tests. The conclusions, which are of general applicability to all cities where the smoke problem is a live question, will be read with interest:

"In the first place, the experiments made before any of the special devices were tried, showed that the ordinary grate is unsuited for smokeless combustion, and that, even with the most careful stoking, the common grate will permit the formation of smoke.

"In the second place, it was clearly demonstrated that smoke prevention and economy do not necessarily go together. The blackest of smoke represents an insignificant amount of fuel, and the tests demonstrated that the devices which produced the least smoke were not the most economical. It should, therefore, al-

ways be assumed that the prevention of smoke involves expense, proper allowance being made therefor.

"Smoke may always be prevented by using coke, but as this is in many cases unavailable, the only remedy lies in the use of such devices as will produce a minimum of smoke, the true principle being, not the combustion of smoke, but the absence of its production.

"The commission recommended the prohibition of dense black smoke, as the trials showed that many devices would accomplish this result. It was also recommended that those devices which showed the best results during the tests be placed in manufacturing establishments with the view of establishing their durability and effectiveness in regular service, and, above all, that the existing regulations be thoroughly enforced by patient and competent officials."—Franklin Institute.

HIGH TEMPERATURES BY A NEW METHOD.—Goldschmidt, a German investigator, obtains high temperature by the oxidation of aluminum, which he effects by heating a powdered mixture of the metal with some common oxid. The heat obtained, together with the reducing action of the aluminum, enables metals to be smelted by this method. Among other practical applications is the following, quoted from "The Chemical News": "A rivet, such as are employed in bridge making, is embedded in a mixture of oxid of iron, sand and aluminum powder. The whole is plunged in sand contained in a wooden box. On top of the aluminum mixture, which must just emerge from the sand in the box, we place a small lump of a mixture of aluminum powder and an easily-reduced oxid, in which is fixed the end of a short piece of magnesium ribbon. The reaction is started by lighting the free end of the magnesium, and we then immediately place more sand on the top of the mixture, so that as little heat as possible may be lost. If at the end of a few moments we empty out the contents of the box, the rivet will be found to be quite red hot and ready to be forged. Working in an analogous manner, we can weld together steel tubes, and the expense will not be more than twopence. We can even fuse

together two bars of soft steel." According to the inventor, the temperature obtained under these conditions may be higher than that realized in the electric furnace.—"Literary Digest."

NOTES FROM JAPAN.—On Sunday, June 11, the new dock belonging to the Ishikawajima Iron Works Company, of Tokio, was opened at Uraga. This small harbor, at the entrance of the Tokio Bay, is the place where Commodore Perry touched on his way to Tokio, or Yedo, as it then was called. Uraga is 1½ hours' steaming from Yokohama. It is just outside of the headland at the mouth of Tokio Bay.

The dock, at the entrance of the harbor, is 451 feet in length, from gates to head, breadth at the bottom 54 feet, and depth from the ground level to bottom of dock 32 feet. The blocks are 4 feet high, and the pumps empty the dock in 1½ hours. It will take most of the merchant steamers which frequent Yokohama, with the exception, perhaps, of the French and Trans-Pacific mail boats, the big-blue funnels boats, and the steamers of the Nippon Yusen Kaisha, which ply on the European line. On the day of the opening ceremony the Japanese Australian liner *Futami Maru* was in the dock.

Inside of the dockyard gates there are a laying-down loft, iron heating furnaces, molding shop, iron shipbuilding shop, fitting shop, boiler shop, smithy and stores. There is also a very fine pair of steel sheerlegs, capable of lifting 60 tons, and a club, in which are placed a couple of good billiard tables. The shops are full of powerful first-class machines, mostly from the best of British makers.

At the ceremony the chairman of the company, the well-known banker, Mr. E. Shibuzawa, made a speech, after which communications were read from the Ministers of Trade. At the conclusion of the speeches the guests, about 700 of whom had been conveyed from Yokohama by the steamship *Kobe Maru*, were entertained at a stand-up lunch. After this function there were jugglers and other shows to see. The directors of the company deserve to have their energy repaid by a large business, but the

drawback, it is thought, will be the distance of the dock from Yokohama.

On the building slips the company have two steam lighters of about 750 tons carrying capacity, for carrying stone for the Osaka Harbor Works. They have hopper bottoms and are of steel. They are about half plated at present. When the ceremony was over the visitors were conveyed back to Yokohama on the *Kobe Maru*, after a very enjoyable day.

This part of Japan is well off for docks now, as, in addition to this one, there are those in Yokosuka, belonging to the Japanese Navy, and the two of the Dock Company at Yokohama. There is also a small mud one at the Ishikawajima works, on the Tokio river. In Kobe there are two slips and a dock in course of construction. At Osaka there is a mud dock. In Kure and Sasebe there are the docks of the Japanese Navy.—"Engineering."

A NEW WRINKLE IN COOLING MACHINES.—A novel application of thermodynamics to domestic purposes has recently turned up in the shape of an air-cooling apparatus for offices, apartments and habitations. It is a somewhat radical departure from previous methods in that the source of the cooling is not, as generally heretofore, the conversion of mechanical work into the abstraction of heat, either directly or indirectly, but merely depends upon the enormous latent heat of vaporization of water. Water from any convenient source is supplied in a thin film to the copper top of a flat convoluted air flue, and a sharp air blast is directed axially along and over this flue, from a special little blower motor. The forced evaportion chills the air flue vigorously and drops the temperature of the whole air blast from 10 to 25 degrees Fahrenheit, according to the rate of evaporation attained. The net result of this arrangement, the details of which are here only sketched roughly, is to send out into the apartment to be cooled about 10,000 cubic feet of air per hour, cooled to a temperature of about 68 degrees, on an expenditure of about 100 watts. By adjusting the machine the air supplied can be sent out without any added moisture or with such a degree of humidity as may be desired, and the temperature may likewise

be varied, although as usually adjusted the temperature of the air delivered is controlled automatically within a few degrees range. Obviously such an apparatus is not intended or adapted for cold-storage work or the like, but within the range required for effective house cooling it is enormously more efficient than any machine which depends on the degradation of mechanical energy. The new machine is manufactured under patents to Dr. Louis Bell, and is about to be placed on the market.—"Electrical World."

A Simple Copying Process.—Reference has frequently been made in the pages of the "American Machinist" to methods of copying writings, drawings, etc., by means of the hektograph or gelatine pad and similar preparations, each having its peculiar good features. I have bought or made and have used a number of these devices, but after considerable experiment I have concluded that the most simple and useful for the everyday wants of the business man or the draftsman is one in which gelatine is not used at all, and which is so readily made, kept in condition, and used, as to be a most convenient substitute for at least a large majority of those that have been proposed.

It is prepared by making a putty of whiting and glycerine in the proportion of about four ounces of glycerine to each pound of whiting. Different samples of glycerine require somewhat different proportions, but the point is to give the mass about the consistency of the putty used by glaziers, or possibly a little harder. The prepared mass is placed in a tin tray about $\frac{5}{8}$ inch deep, and carefully smoothed down with a putty knife or similar tool, and finally with a piece of sheet-rubber packing about $\frac{1}{8}$ inch thick, used in the manner of the well-known window cleaner.

The ink used may be almost any of the hektograph inks whose coloring matter is aniline. The following preparation of ink is perhaps as simple as any: Violet aniline, $\frac{1}{2}$ ounce; sugar, $\frac{1}{2}$ dram; boiling water, 2 ounces. Mix thoroughly, and when cold add alcohol and glycerine, of each 1 dram, and dilute carbolic acid, 2 drops. The usual dies sold in the drug stores for coloring fabrics are proper for this purpose, but those for color-

ing cottons should be chosen rather than those for woolens. The violet aniline makes the strongest ink, although other colors do good work, the proportionate number of copies that may be made being about as follows for the usual colors: Violet, 60 copies; red, 40 copies; green, 30 copies; black, 15 copies.

Much of the success attained is due to good ink, whatever the copying surface used, and, generally, the number of copies which are said to be possible with a certain form of pad is greatly exaggerated. The pad above described is used in the same manner as the gelatine pad, but it has the great advantage that after use every trace of color may be instantly wiped off with a sponge and clean, cold water, leaving the pad ready for use by taking up the surplus moisture with a piece of old newspaper laid flat, smoothed down, and in a minute removed. In some cases, after not being used for a considerable time, the pad may need moistening before use, which may be done with the sponge, and the surplus moisture removed as before.

The economy of this form of pad may be readily appreciated from the fact that whiting costs but about 2 cents per pound and glycerine 4 cents per ounce. A pad of the proper size for a note sheet requires 1¼ to 2 pounds of whiting. When worn away by repeated washings, so as to be too thin for convenient use, the remaining material may be added to the new.—Oscar E. Perrigo, in the "American Machinist."

Naval Tests of Marconi Wireless Telegraphy.—A special despatch from London of August 5 says: The mimic war between England and Ireland, which began last Saturday, was brought to a close to-day. Sir Compton Domvile, with the British fleet, won, to use the language of the turf, in a canter. With the detached squadron was the *Europa*, which had been fitted in a hasty manner with the Marconi system of wireless telegraphy. In the other portion of the fleet the *Alexandra*, Sir Compton Domvile's flagship, and the cruiser *Juno*, on which was Signor Marconi himself, had been also fitted with the system. The *Juno* was ordered to get in touch as soon as possible with the *Europa* on Monday afternoon. It was a little after 5 o'clock when the instrument in

Signor Marconi's cabin gave some feeble ticks, and then a message was rapped out that the *Europa* had reached her convoy and was coming to communicate the news to the flagship.

When the *Juno* received this message she was more than forty miles from the *Europa*, and more than seventy from the convoy. Turning about, she proceeded back on her course, and at 7.30 o'clock, when still more than thirty miles from the flagship, she repeated the intelligence she had received from the *Europa*. A second message, sent in the same way, is mentioned by a correspondent, who estimated the distances of the *Alexandra* at the time as thirty miles from the *Juno*, fifty-five miles from the *Europa*, and eighty-eight miles from the convoy. He says, and everyone must agree with him—that it is a veritable triumph for Signor Marconi.—"Electrical World."

The New Channel in New York Harbor.—When it is said that the mud and sand to be removed from the New Nork harbor to make the new channel to the sea, if deposited in the East River, would be sufficient to make the river dry land from shore to shore and from the Battery to Hell Gate, some idea of the size of the colossal undertaking may be obtained. It is estimated that nearly 50,000,000 tons of mud and sand must be removed in order to make the East Channel 40 feet deep and 2,000 feet wide. Congress has appropriated the money, the engineers have drawn the plans, and contracts are being awarded. In order to make the channel it is considered necessary to build new dredges, which will draw up the sand by means of suction pumps. These dredges will be 320 feet long and nearly 48 feet wide, and will have a capacity of 8,000 tons an hour. It will take a year to build the dredges and probably two years more to do the work. The engineer of the Mersey Dock Board recently described the progress of work at the Mersey bar by means of the two huge pump dredges built at Barrow-in-Furness. Whereas at the commencement, in 1890, the shallowest water across the bar was 11 feet at low water of spring tides, there is now a channel of 1,500 feet in width, having practically no less than 27 feet of water in any part on the same condition of tide. The amount of sand

which had to be removed from the bar itself in order to effect this has been 22½ million tons, and from the bar and main channel 41½ million tons.—"Iron Age."

THE VOLTAIC CELL.—A clear and widespread appreciation of the existing limitations of the voltaic cell as an energy producer would save the community much money every year. Claims are constantly being made by inventors for the superior merits of their new voltaic combinations over engines and dynamos. The law of conservation of energy does not, of course, interfere with any such claim, because the question is entirely one of cost. What is needed is a general recognition of the fact, fully understood by those versed in the science, that a cell which consumes zinc cannot compete commercially with a boiler which consumes coal, so long as zinc requires to be produced by the operation of coal-consuming furnaces.—"Electrical World."

SHIPS.

UNITED STATES.

Cruisers, 14-19.—Bids for these six protected cruisers, the chief characteristics of which were given in the May issue of the JOURNAL, will be opened on the second day of November. Since the date alluded to was published several changes have been made in the dimensions, so that these now read:

Length on load water line, feet	292
Extreme breadth at load water line, feet	44
Trial displacement, tons	3,200
Mean draught on trial, feet and inches	15-9
Greatest draught full load, feet and inches	16-11
Total bunker capacity, tons, not less than	700
Coal on trial, tons	470
Feed water, trial, tons	40
Speed on trial, knots (at least.)	16½
Horsepower main engines, total	4,500
Horsepower boilers	4,700
Full-load displacement, tons	3,500

General engine data:

Diameter H.P. cylinder, inches	18
Diameter I.P. cylinder, inches	29
Diameter each L.P. cylinder, inches	35½
Stroke, inches	30
Revolutions, full power, per minute	172
Steam pressure at boilers	275
Steam pressure at engine	250
Diameter of crank shaft, inches	9¼
Diameter of crank pins, inches	9¼
Length of crank pins, inches	11
Diameter of axial hole in shaft, inches	5
Diameter of piston valves, inches	11

The sequence of cranks in turning centers is H.P., I.P., forward L.P. and after L.P., while the sequence of the cylinders from forward is, forward L.P., H.P., I.P., after L.P.

The boilers will be of the straight tube water-tube type and six in number, aggregating a heating surface of 12,600 square feet, and a grate surface of 314 square feet. There will be two smoke pipes 70 feet high from the grate level.

Battleships.—Progress of work on the following battleships is noted from estimates in recent reports, and are mere general indications:

Alabama, 90 per cent. completed. Preliminary contract trial will take place August 28.

Illinois, 80 per cent. completed.

Wisconsin, 70 per cent. completed.

Maine, 10 per cent. completed.

Ohio, 4 per cent. completed.

Missouri, work just begun.

Albany.—Notice has been given that this cruiser will be turned over to the Government before the close of the year. Much interest attaches itself to this vessel, as, while she is a sister ship to the *New Orleans*, which has given so much satisfaction as a fighting machine, she will be a decidedly *improved New Orleans*, having been completed under the inspection of our own naval experts, and embodying many changes from the original design. Lieutenant Harold P. Norton, U. S. N., has been the representative of the Bureau of Steam Engineering in this superintendence and inspection, and we hope to present a complete description by this officer of the vessel, together with the report of her trial, as soon as the latter takes place.

Kearsarge and **Kentucky.**—These battleships, building at Newport News, are rapidly approaching completion. Had it not been for the recent yellow-fever scare in that vicinity it is probable that the trial of the *Kearsarge* would take place in September, though now the prospect is that it will be about November before she will be fully ready for this function. The *Kentucky's* trial should closely follow that of her sister ship.

U. S. S. Dahlgren.—The *Dahlgren*, officially known as torpedo boat No. 10, was successfully launched from the yard of her builders, the Bath Iron Works, Bath, Me., on 29th May. Her contract calls for 30½ knots speed on a displacement of

about 150 tons. The British 30-knot boats have just twice this displacement, viz: 300 tons, and all the other American 30-knot vessels, with the exception of the *Dahlgren's* sister, *T. A. M. Craven*, also building at Bath, have displacements varying from 250 to 400 tons. The *Dahlgren* is 151 feet long and 16 feet 6 inches beam, with a mean draught, loaded, of 4 feet 8 inches. She is very little larger than the *Foote*, *Rodgers* and *Winslow*, but whereas the latter vessels have machinery capable of indicating but 2,000 horsepower, the *Dahlgren's* have been designed for over 4,200 horsepower. It is also interesting to note that whereas the vessels of the *Foote* class have a trial speed of 24½ knots, the *Dahlgren* will have a speed of 30½ knots, or 6 knots more.

The steel worked into the vessel is all galvanized, and it is 40 per cent. stronger than ordinary ship steel. The machinery of the *Dahlgren* consists of two triple-expansion engines driving twin screws. The cylinders are 17, 25 and 37 inches diameter respectively, the stroke being 21 inches. It will be noticed that the stroke is from 3 to 5 inches longer than the usual torpedo-boat engine, but this long stroke has many advantages, one being that it allows the revolvtions to be kept down. Whereas 400 revolutions and 1,200 feet piston speed is usually adopted for the speed of a torpedo-boat engine, the *Dahlgren's* engine will turn up to about 340 revolvtions when indicating about 4,200 horsepower. There are two Normand water-tube boilers in the vessel, designed to work at 230 pounds pressure. The total grate surface is 118 square feet. The *Dahlgren* will carry 22 tons of coal and 6 tons of feed water. She will be fitted with two deck torpedo guns, discharging 18-inch Whitehead automobile torpedoes, and she will also carry four 1-pounder rapid-fire guns. She was launched with all her machinery on board, and is at present practically completed. Her short, straight smoke-stacks, rising only just above the awning, with the galley between them, make her appearance quite different from any other American boats. She has two conning towers but no turtleback forward, a long sheer and one small signal spar. She carries two 14-foot cedar boats on deck. She has an electric plant and the usual

auxiliaries. Her interior arrangements are about the same as all other vessels of this class. The officers and petty officers are berthed aft, and the crew are located forward.

U. S. S. Stringham.—The *Stringham*, the largest and costliest torpedo boat yet built for the United States Navy, was launched from the yards of the Harlan and Hollingsworth Company, Wilmington, Del., on June 10. She will be the pioneer oceangoing vessel of her class, and her guaranteed maintained speed will be 30 knots. The *Stringham's* keel was laid on March 21, 1898. Her length is 225 feet; breadth, 22 feet; mean draught, 6 feet 6 inches, and displacement, 340 tons. This is 70 tons larger than the *Farragut*, twice as great as any other American torpedo boat built or building, and is within 60 tons of the weight of some of the destroyers. Two vertical triple-expansion engines, driving twin screws will develop 7,200 horsepower when forcing the boat at her maximum speed. This power is greater by 1,500 than that of the *Farragut* or any of her class, and equals that of most destroyers. The normal coal supply is 35 tons, but the bunker capacity of the *Stringham* is 120 tons, and with this she will cruise over 1,000 knots. The *Stringham* will carry two 18-inch Whitehead torpedo tubes and seven 6-pounder semi-automatic guns. Her crew will consist of four officers and twenty-eight men.

BRAZIL.

Marechal Floriano.—The cruiser *Marechal Floriano* (3,162 tons), constructed at La Seyne by the Forges et Chantiers de la Méditerranée, for the Brazilian Government, was launched on the 6th of last June.

ENGLAND.

Names Given New Armored Cruisers.—The armored cruiser of 9,800 tons and 23 knots which will be constructed at Portsmouth after the launching of the armored vessel of 15,000 tons and 18,000 horsepower, *London*, will be called the *Kent*.

The order has just been given to Pembroke to put on the stocks *No. 5*, an armored cruiser of the same type, of 23 knots, which will be called the *Essex*.

The armored cruiser ordered at the Fairfield Company, of Glasgow, will receive the name of *Bedford*, and that which has been ordered at the London and Glasgow Shipbuilding and Engineering Company, of Glasgow, the name of *Monmouth*.

Barham.—The third-class cruiser *Barham*, of 1,830 tons, made on the 17th of May a forced-draft trial, securing 210 revolutions and 6,150 horsepower, with a full speed of 19 knots. At times the power attained was 6,400 horsepower.

H. M. S. Vengeance, recently launched by Messrs. Vickers, Sons and Maxim, Limited, Barrow-in-Furness, is a first-class battleship laid down on August 23, 1897, and to be completed next spring at a cost of £870,419, according to the navy estimates. She is 390 feet long between perpendiculars, 74 feet beam, and some concessions have been made in her design to insure a draught of only 26 feet when she is in full working order. The displacement then will be 12,950 tons, of which 8,550 tons are due to the hull. She may be said to belong to the *Canopus* class, although, having been ordered a year later, she embodies several changes in detail. Like the five vessels of the type named, her side armor is of 6 inches thickness instead of 9 inches; but, the face being specially hardened, the shot-resisting power will be greater than that nominally corresponding to the thickness. The broadside armor is 14 feet deep, being carried 5 feet below the load-water line. The length is about 196 feet, leaving about 100 feet forward and aft, but this is more nominal than real, for instead of the 'thwartship bulkhead being, as has hitherto been general, at right angles to the line of the ship, the end armor is arranged in the form of a $>$, the point being towards bow and stern, and as this is from 12 inches to 8 inches thick, thinning towards the bottom, it extends the armor protection. Again, the side armor is carried to the ram as 2-inch nickel-steel plating, which broadens as it extends forward till it reaches from top to bottom, and thus the ram is greatly reinforced. Here it may be said also that the forefoot is greatly cut away, as is also the deadwood aft to improve the circle turning of the ship. Abaft the citadel the side plating is made thicker at the load line for a depth of quite 10 feet. The protective deck

is 2 inches thick, and, as usual, is curved from the bottom of the side armor to above the water line in the center. This curve enables the engines to be entirely below the deck, obviating the necessity for an armored coaming round the cylinders. There is the usual bunker protection, and coal is carried both under and upon the protective deck, the other levels within the length of the citadel being middle, main, upper and boat decks. The last named, however, does not extend the full width of the ship. At the end of the ship there is a platform below the protective deck.

The barbettes for the pairs of 12-inch guns are immediately within the > at the forward and after end of the citadel. These are 36 feet 8 inches in diameter, of 12-inch Harveyed nickel-steel. There are four casemates on the main deck on each broadside, there being twelve 6-inch quick-firing guns in all, four of them being placed on the upper deck. The bow and stern quick-firing guns have a range to 28 degrees abaft or forward, respectively, and the broadside guns the usual 120 degrees. The casemates are in plan very irregular octagons, the end ones being almost triangular. There are, in addition, eighteen smaller guns, three 12-pounders in the citadel on each broadside on the upper deck, and four on the main deck, two firing forward and two aft. The machine guns are on the bridges and military tops. The masts are very lofty and carry searchlights, which are placed on a platform well raised. There are two navigating bridges, one forward and one aft, and two conning towers, the forward one having 12-inch Harveyed nickel-steel and the after 3-inch nickel-steel. The voice tube and ammunition hoists are armored.

The *Vengeance* is, of course, propelled by twin screws, each driven by an independent set of triple-expansion engines, with three vertical cylinders, of 6,750 indicated horsepower, the aggregate being 13,500. This is attained with the engines making 108 revolutions, and with a steam-boiler pressure of 300 pounds per square inch, reduced to 250 at the engines, and at this point it may be said that the total weight of the machinery, main and auxiliary, including boilers and the water in them, is about 1,290 tons. The high-pressure cylinder is

30 inches in diameter, the intermediate-pressure 49 inches, and the low-pressure 80 inches, the stroke being 51 inches. The cylinders are separate and independent castings, stayed together, and all the barrels are jacketed. The high-pressure and intermediate-pressure cylinders are each fitted with one valve of the piston type, and the low-pressure cylinder with the ordinary flat valve fitted with equilibrium rings. The valve gear is the double-eccentric ordinary link motion. The straps are separate from the rods, and of forged steel, lined with white metal. Double-cylinder reversing engines are fitted, which in 30 revolutions turn the main engines from full gear ahead to full gear astern. The starting position, it may be added, is amidships.

The bottom frames of the engine are of cast steel, and are bolted together to form one complete bedplate for each set of engines. Bolts, and not studs, are used for securing the main bearing caps. The front columns are forged steel, and the back columns are of cast iron with guides bolted to them.

The pistons are of cast steel of conical form, the piston rods of solid wrought steel 8¼ inches in diameter, with a substantial collar under the piston. Ample surface is provided for the ahead and astern guides. The connecting rods are 8 feet 6 inches long, center to center. The crank and propeller shafts are of forged steel, finished complete at the company's works at Sheffield. The couplings are forged solid with the shaft, except the wrought-iron disconnecting coupling. The total length of the shaft from the main engine to the propellers is about 124 feet. The crank shaft is made in three interchangeable parts, the external diameter being 16½ inches with a 9-inch hole. The length of the main bearings is 9 feet 6 inches. The crank pins are 18 inches in diameter outside and 9½ inches inside, and 20 inches long. The cranks are set at an angle of 120 degrees. The sequence is high pressure, low pressure, and intermediate pressure, the high-pressure cylinder being placed at the forward end and the low-pressure aft. The propeller shafting between the crank shaft and the stern tube is 15½ inches outside and 8¾ inches inside diameter. The stern shaft for the stern tubes is 16½ inches outside, exclusive of the gun-metal casing, and 9 inches inside.

The shafting beyond the stern tube is 17½ inches outside and 10 inside. The after coupling of the propeller shafting is so arranged that the after length of shafting can be withdrawn in a forward direction without disturbing the stern-tube shaft. The shafting within the tube is effectively cased with gun metal. The thrust block consists of horseshoe collars faced with white metal having a thrust surface of 1,800 square inches for each set of engines. The stern tubes are of gun metal, cast in one length, fitted with lignum vitæ bearings in the usual Admiralty manner. The propellers are four-bladed, of bronze, and 17 feet in diameter, and work inwards. The turning engines, with two cylinders, are capable of turning the main engines completely round in eight minutes with two-thirds the working pressure of the boilers, and when exhausting into the atmosphere. Hand-turning gear is also provided.

The condensers are circular, made of rolled naval-brass plates with gun-metal mountings. One main and one auxiliary condenser is placed in each engine room. The total cooling surface of the two main condensers is 14,500 square feet, and of the auxiliary condensers 2,200 square feet. These latter are used for condensing the steam from the auxiliary engines throughout the ship, and are fitted with a combined circulating and air pump. The condenser tubes are of solid-drawn brass, untinned, ⅝ inch in external diameter and .048 inch thick. The pitch of the tubes is $\frac{8}{8}\frac{1}{2}$ inch. One main air pump is fitted to each main engine, 30 inches in diameter by 19 inches stroke, and is driven by means of levers from the low-pressure cylinder crosshead. These pumps deliver into a hotwell. Two circulating-pump engines are fitted to each engine room. They are of the centrifugal type, having impellers 45 inches in diameter, driven by a compound engine. The duty expected of these pumps is 1,200 tons of water from the bilge per hour with two-thirds the steam pressure, and exhausting into the atmosphere. Either of the two sets in each engine room is large enough for the duty. The circulating sea-suction pipes are 17 inches in diameter and the discharge 19 inches. These engines are placed as high as prac-

ticable in the engine rooms. The hotwell is of 100 cubic feet capacity and is fitted low down in each engine room. The main air pumps deliver into these hotwells. A pumping engine of the duplex type is fitted to draw from these hotwells and discharge through grease-extractor tanks into the feed tanks. These pumps are also connected to the main condensers. Each grease extractor has over 10,500 square inches effective filtering surface, and the extractors are easily cleaned. Tanks for feed water of about 70 tons capacity are provided in wings and double bottoms. These tanks can be filled by means of injectors at the rate of 50 tons per hour. Means are provided for the admixture of lime with the feed water. The feed pumps (by Messrs. Weir), six in number, are fitted in the boiler rooms; one in each compartment is arranged as a main and one as an auxiliary feed pump. They are of such a capacity that three are sufficient for the full power. The pressure in the feed pipes arranged for is 700 pounds per square inch.

The main steam pipes are of steel, lap-welded with butt-strap over the weld for pipes down to, but not including, 6 inches. Below this they are solid-drawn steel down to $1\frac{1}{2}$ inches in diameter; below this again they are of solid-drawn copper. Reducing valves are fitted in the main steam pipe in each engine room between the main shut-off valve and the regulating valve. Separators are fitted in the engine room, one each side, on the boiler side of the self-closing valve.

There are twenty boilers of the Belleville type, with economizers, and all recent improvements. Each boiler can be used independently of the others, and works at 300 pounds per square inch. The boilers are arranged in three compartments, eight in each of the forward and middle boiler rooms, and four in the after. There is no middle-line bulkhead in the boiler rooms. Fifteen of the boilers have nine elements of large tubes $4\frac{1}{2}$ inches in external diameter, and five boilers consist of eight elements of large tubes $4\frac{1}{2}$ inches in external diameter, each element containing seven pairs of tubes. All the boilers are fitted with economizers, those in the wings of the ship having six elements, and the remainder seven elements, in each case. The economizer elements consist

of ten pairs of tubes 2¾ inches in external diameter. The heating surface is 21,760 square feet in the main tubes, and 12,010 square feet in the economizers, the total being 33,770 square feet. The boiler tubes are all of British manufacture, as also the material from which they are drawn. The tubes are all solid drawn, finished cold, carefully annealed after manufacture, and subjected to severe tests. Each tube is coated externally with zinc by electro deposition at the Barrow Works.

As to the auxiliary engines in the ship, some brief reference may be made. The distilling machinery, by Messrs. Weir, consists of two evaporators capable of evaporating from sea water 68 tons per 24 hours when worked not compound and 42 tons when worked compound. The two distillers produce 40 tons of fresh aërated water per day for drinking at 15 degrees Fahrenheit above that of the circulating water, with circulating water at not less than 75 degrees Fahrenheit. The electric-light machinery consists of three sets of combined engines and dynamos, the electromotive force being 80 volts for all loads from 10 up to 600 ampères.

There are two double-cylinder, direct-acting steering engines, by Messrs. Caldwell & Co., Glasgow, of sufficient power to move the rudder from hard-a-port to hard-a-starboard, and *vice versa*, through an angle of 70 degrees in 30 seconds, with the vessel proceeding at a speed of 18½ knots and a pressure in the steam-pipes of 200 pounds per square inch. There are four sets of engines and pumps for air compressing, two boat hoists, two refrigerating machines, two coal hoists, five ash hoists, five air-blowing engines, and, for ventilating the ship, there are eight electrically-driven fans, six with 3-foot 6-inch and two with 3-foot discs. These are distributed throughout the ship. There are also two steam fans 7 feet 6 inches in diameter, one in each engine room, and four fans of 8 feet diameter and two of 6 feet diameter for the boiler rooms. Each fan is double breasted.

The ship will have a better appearance than the *Canopus* class, for, in addition to other changes, both funnels are of the same diameter—11 feet. They are 90 feet high from the grates, and are spaced at 23 feet centers. The spacing of masts and funnels

could be more effective from the point of view of appearance.—"Engineer."

H. M. SS. Hermes and **Highflyer.**—The *Hermes* completed her trials on June 13, and the *Highflyer* ran her official trials between June 20 and 30. Both ships are identical, and the principal dimensions are: Length between perpendiculars, 350 feet; breadth, extreme, 54 feet; displacement, 5,600 tons. There is a cellular bottom extending the full length of the engine and boiler spaces, and before and abaft these the watertight flats of the magazines, etc., continue the double bottom right to the stem and stern. Under the protective deck, the side compartments for the full length of the boiler space are utilized for stowing coal. The hull is subdivided by longitudinal and transverse bulkheads into numerous watertight compartments as usual, the number of watertight doors having been reduced to a minimum, and all being worked from the main deck as well as from below. The stern post, struts and stem are of phosphor-bronze. The stem is of the usual ram form, and the structure behind is especially strong and efficiently connected to the general framework of the vessel with a view to the contingency of ramming. The rudder, also of phosphor-bronze, is of the balanced type and controlled by Harfield's compensating gear below the protective deck. The vessel being intended for foreign service and long cruises at sea, in which the maintenance of a uniform speed becomes essential, she has been completely covered to above the load-water line with teak of a minimum thickness of 3½ inches, and coppered. To secure steadiness of gun platform so necessary in a vessel intended for war purposes, bilge keels extending for about half the vessel's length amidships have been fitted.

The protection of the vessel consists of a curved deck extending from stem to stern, ranging from 3 inches to 1½ inches in thickness, covering the whole of the propelling and steering machinery, boilers, magazines, etc.

The reserve bunkers are on the protective deck over the machinery space, and, whilst affording a water-line belt of coal protection they, being subdivided into watertight compartments, give additional security in the event of damage. An armored

conning tower of Harveyized steel is placed forward, fitted up with the usual means of navigating the vessel and directing operations while in action, the whole of the connections for which are protected by a steel tube extending to the protective deck. Three searchlights are operated from these bridges, and the vessel throughout is fitted with a complete installation of electric light. Her armament consists of eleven 6-inch and eight 12-pounder quick-firing guns, and a number of smaller machine guns. The guns are all protected by extra-thick shields. Two submerged torpedo tubes are fitted forward, capable of working the latest pattern torpedoes.

The propelling machinery consists of two sets of triple-expansion engines, fitted in two separate engine rooms, each set having four inverted cylinders and four cranks. The high-pressure cylinders are 26 inches in diameter, the intermediate-pressure cylinders, 42 inches in diameter, and each of the four low-pressure cylinders, 48 inches in diameter, all adapted for a stroke of 2 feet 6 inches. The cylinders are all separate and independent castings, each fitted with a cast-iron barrel or liner and steam jacketed. Each of the high-pressure and intermediate-pressure cylinders is fitted with piston valves, and each of the low pressure with flat slide valves, all worked by the usual double-eccentric and link-motion valve gear. The reversing engines are of the all-round type, capable of being reversed, with worm and wheel gear; all the levers being fitted with a slot and adjusting screw to allow of the expansion of steam in the cylinders being altered. The back columns are of cast iron, fitted with separate guide faces, and the front columns are of forged steel, the engines being arranged with the starting platform amidships. The condensers are of brass and placed at the wings. There are two centrifugal pumps of gun metal, each worked by an independent engine, one in each engine room, and arranged with a cross connection, so that either or both condensers can be supplied with cooling water from either pump. The feed, bilge and hotwell engines are all independent and separate from the main engines. Feed-water filters are fitted to prevent any impurities reaching the boilers. The crank, thrust

MEAN RESULTS OF TRIALS OF H. M. S. *HERMES*.

.....	First 12-hours' 1,000 I.H.P. consumption trial.		Second 12-hours' 1,000 I.H.P. consumption trial.		30-hours' 2,000-I.H.P. coal-consumption trial.		30-hours' 7,500-I.H.P. coal-consumption trial.		10,000-I.H.P. coal-consumption trial.	
Date of trial	May 31, 1899.		June 1, 1899.		May 30, 1899.		June 4, 1899.		June 6, 1899.	
	Stbd.	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*
Mean steam in boilers, pounds	239	238	166		270		264		240	
Mean steam at engines, pounds	169	176	124		155		223	222	230	228
Mean cut-off in H.P. cylinder, pr. ct.	20		About 50		About 28		56	56	72	70
Mean vacuum, inches	26.2	26.1	26.7	27	25.4	25.6	25.2	25.9	24.4	24.5
Mean revolutions	84.5	85.3	86.3	86.7	109	108.9	165.3	166.4	181.6	183.9
Mean pressure in cylinders, High, pounds	13.9	10.3	23.9	25.4	34.3	35.1	88.2	91.3	100.0	95.4
Mean pressure in cylinders, Intermediate, pounds	10.5	10.1	8.6	9.4	15.8	14.1	35.6	35.7	40.1	42.1
Mean pressure in cylinders, Low forward, pounds	5.15	7.46	3.8	3.7	6.2	8.5	14.9	16.3	20.6	21.3
Mean pressure in cylinders, Low aft, pounds	4.8	6.04	3.5	3.6	5.5	6.7	14.3	16.7	20 2	21.8
I.H.P. High	89	71	166	177	302	307	1,173	1,220	1,471	1,411
I.H.P. Intermediate	186	182	156	171	361	323	1,237	1,251	1,529	1,627
I.H.P. Low forward	119	174	90	89	186	254	676	743	1,027	1,075
I.H.P. Low aft	112	141	84	85	165	201	648	765	983	1,101
Total I.H.P.	506	568	496	522	1,014	1,085	3,734	3,979	5,010	5,214
Gross total I.H.P.	1,074		1,018		2,099		7,713		10,224	
Mean coal, pounds per I.H.P.	2.61		2.31		2.32*		1.59		1.58	
Speed, knots	10.45		10.4		13.4		18.8		20.5	

* Owing to this high coal consumption, the Admiralty ordered this 30-hours' trial to be repeated.

and propeller shafting is of forged steel and hollow. The crank-pins are fitted with centrifugal lubricating apparatus. The propellers are of gun metal, each propeller having three adjustable blades.

Steam is supplied by eighteen Belleville water-tube boilers of the latest type fitted with economizers, and adapted for a working pressure of 300 pounds. The boilers are arranged in three boiler rooms, and there are three funnels. Fans and engines are fitted in the stoke holds to insure the necessary supply of air, air-pumping engines being also fitted to deliver air direct into the furnaces and combustion chambers.

MEAN RESULTS OF ADDITIONAL TRIALS OF H. M. S. *HERMES*.

.....	Second 30-hours' 2,000-I.H.P. coal-consumption trial.		Eight-hours' trial at 9,000 I.H.P., with auxiliary-machinery exhaust steam passing to the low-pressure receivers of main engines.	
Date of trial	June 9 and 10, 1899.		June 13, 1899.	
Mean steam in boilers, pounds	196		270	
Mean steam at engines, pounds	126		247	
	Starboard.	*Port.*	*Starboard.*	*Port.*
Mean cut-off in H.P. cylinder, per cent.	35	32.7	56	56
Mean vacuum, inches	26.0	27.0	25.1	25.2
Mean revolutions per minute	111.2	110.6	174.4	176.8
Mean pressure in cylinders, High, pounds	40.2	35.0	105.0	96.6
Mean pressure in cylinders, Intermediate, pounds	16.1	15.9	31.2	31.7
Mean pressure in cylinders, Low forward, pounds	6.86	6.21	23.0	21.8
Mean pressure in cylinders, Low aft, pounds	5.78	5.47	19.5	19.6
I.H.P., High	360	312	1,470	1,374
I.H.P., Intermediate	377	362	1,143	1,176
I.H.P., Low forward	209	189	1,099	1,058
I.H.P., Low aft	176	166	934	949
Gross total I.H.P.	2,151		9,203	
Coal per I.H.P. per hour, pounds	1.78		1.52	
Speed per hour, knots	13.4		20.0	

The vessel is also fitted with the usual auxiliary machinery, viz: a complete distilling plant to supply fresh water to the boilers, and also for drinking purposes; two sets of engines and dynamos for producing the necessary current for electric lighting;

one double-cylinder engine with the necessary gear for steering purposes; two complete sets of air-compressing engines and pumps, with the air reservoirs, for charging torpedoes; and one refrigerating machine of the cold-air type, with the necessary cold chamber for ship's provisions. The exhaust steam from all of the auxiliary engines in the machinery room, including the steering engines, can be utilized for evaporation or other uses.

Since the first trials, the vessel has made two runs, one at low power, because on the former occasion the conditions at this power did not admit of reliable results being realized; and, as will be seen from the table of results appended, the coal consumption was greatly reduced, being 1.78 pounds. The second supplementary trial was run at 9,000 indicated horsepower, with the exhaust steam from the auxiliary machinery passing into the low-pressure receiver of the propelling engines, an arrangement which gave satisfaction.

The *Highflyer* trials gave even more satisfactory results, the coal consumption being unprecedentedly low on the full-power run, when the boiler pressure was maintained at 292 pounds, and at the engines the mean was 228 pounds. The links were set to cut off at 74 per cent. of the stroke, and the starboard engine, running at 187.6 revolutions, made 5,262 horsepower. The port engine ran 186.5 revolutions. It will be noticed from the table that the power got from the high and intermediate cylinders is almost equal, while the powers of the low-pressure cylinders also closely approximate each other. The variation is practically within the limits of error. This same remark holds good as regards the other trials, the low-pressure cylinders each giving about 66 per cent. of the power indicated in each of the high and intermediate. This arrangement gave most satisfactory results as regards engine balancing, there being practically no vibration. The collective power on this trial was 10,344 horsepower. The speed of this ship was 20.1 knots, which more than meets the expectations of the design. On the 30-hours' trial at continuous sea speed, the steam pressure was 260 pounds, and at the engines it was reduced to 223 pounds. The cut-off was arranged at 56 per cent. of the stroke, and at 169.7 revolutions the starboard

engine gave 3,828 horsepower, while the port engine recorded 3,816 for 168.1 revolutions. The collective power was thus 7,644

MEAN RESULTS OF TRIALS OF H. M. S. *HIGHFLYER*.

.....	Contractors' 30 hours' 2,000-I.H.P. coal-consumption trial.		Contractors' 30-hours' 7,500-I.H.P. coal-consumption trial.		Contractors' 8 hours' full-power trial at 10,000 I.H.P.	
Date of trial	June 20, 21, '99.		June 22, 23, '99.		June 27, '99.	
Mean steam in boilers, pounds	214		260		292	
Mean steam at engines, pounds	125		223		228	
Mean cut-off in H.P. cyls., pr. ct.	34		56		74	
	Stbd.	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*
Mean vacuum, inches	26.5	26.0	25.4	26.1	25.6	25.4
Mean revolutions	110.1	110.4	169.7	168.1	187.6	186.5
I.H.P. High	346	320	1,313	1,265	1,610	1,523
I.H.P. Intermediate	341	360	1,087	1,157	1,515	1,513
I.H.P. Low forward	202	191	724	719	1,067	1,040
I.H.P. Low aft	190	185	704	675	1,070	1,006
Gross total I.H.P.	2,135		7,644		10,344	
Coal per I.H.P. per hour, pounds	1.62		1.49		1.407	
Speed per hour, knots	12.5		19.4		20.1	

indicated, while the speed of the ship was 19.4 knots. The addition, therefore, of 2,700 indicated horse-power to the power, equal to 34 per cent., barely added three-quarters of a mile to the distance run in each hour. This 19½ knots speed was got for an expenditure of 5 tons of coal per hour, which, in view of the displacement, 5,600 tons, is a very satisfactory result, proclaiming not only a high mechanical efficiency, but a beautiful form of ship and great propulsive efficiency. On the low-power trial it was preferred to work the boilers at a high-pressure, reducing it greatly at the engines and cut-off steam in the cylinders at a comparatively late period of the stroke, rather than with a high initial pressure and an early cut-off. The steam pressure was, at the boilers, 214 pounds and at the engines, 125 pounds; this latter enabling the simple auxiliary engines to be worked at a better economy. Sir John Durston, K.C.B., the

engineer-in-chief, was present at the trials, with Mr. J. Smith, inspector of machinery, Mr. Ellis and Mr. Gregory for the Devonport Dockyard and Mr. Frost for the steam reserve. Mr. Alexander Gracie, the engineer manager at Fairfield, as well as Sir John Durston, is to be congratulated on the results in both ships.—"Engineering."

H. M. S. Ocean.—Her Majesty's first-class battleship *Ocean*, which has been built at Her Majesty's dockyard, Devonport, and engined by Messrs. R. and W. Hawthorn, Leslie & Co., of Newcastle-on-Tyne, commenced her contract trials on the last week of July.

This vessel is the first ship of the *Canopus* type to undergo her steam trials, and is also interesting as being the first battleship in Her Majesty's service which has been tried with Belleville boilers, although, of course, many cruisers have passed through their trials fitted with this type of boiler. She is also of interest as being the first battleship of modern type which has ever been built at Devonport, although two other vessels of this class are now in hand at that dockyard.

The main propelling machinery of the *Ocean* consists of two sets of vertical, three-crank, triple-expansion engines. The diameters of the cylinders are 30 inches, 49 inches, and 80 inches, by 51-inch stroke, and the engines are designed to run at 108 revolutions per minute when indicating full power. All the cylinders of the engines are fitted with separate liners, the high-pressure cylinder being controlled by a piston valve and the intermediate and low-pressure cylinders by double-ported slide valves. All the valves are worked by ordinary double-bar link motion. The bedplates are of cast steel, the back columns being of cast iron and the front columns wrought steel. The condensers, which are of cast gun metal, have a total heating surface of 14,500 feet. All the auxiliary machinery usual in vessels of this class has been fitted.

The boilers, which are twenty in number, are of the Belleville type fitted with economizers, ten of the boilers having nine elements and ten having eight elements. The tubes, which are all of solid-drawn steel, galvanized externally, are $4\frac{1}{2}$ inches outside

diameter in the generator elements and 2¾ inches diameter in the economizer elements. The total heating surface is 37,715 square feet, of which 24,155 square feet are in the generator elements, and 11,560 square feet in the economizer elements. The total grate area is 1,035 square feet.

The boilers are arranged in three water-tight compartments in two groups of eight and one group of four. The steam pressure is 300 pounds per square inch in the boilers, which is reduced to 250 at the engines by means of Belleville reducing valves.

The contract trials specified are as follows:

1. A preliminary trial at sea.

2. A 30-hours' trial at one-fifth power, *i. e.*, 2,700 indicated horsepower.

3. A 30-hours' trial at 10,250 indicated horsepower.

4. An 8-hours' trial at full power, viz: 13,500 indicated horsepower.

On July 26 the vessel was taken to sea for her preliminary trial, and the machinery was worked gradually up to about 100 revolutions. Everything worked without the slightest difficulty, and on the 27th the vessel proceeded to sea for her 30-hours' trial at one-fifth power. The results of this trial are tabulated below. The trial passed off most satisfactorily, no difficulties of any sort being experienced, the machinery running very smoothly without the slightest signs of heating.

MEAN RESULTS OF 30-HOURS' TRIAL.

		Starboard.	*Port.*
Mean steam in boilers, pounds		210	210
Mean steam at engines, pounds		184	184
Mean vacuum, inches		27.8	27.5
Mean revolutions		66.6	67.0
Mean pressure in cylinders,	High, pounds	41.6	38.2
	Intermediate, pounds	16.2	15.4
	Low, pounds	4.6	4.2
I.H.P.	High	506	466
	Intermediate	527	501
	Low	398	369
Total I.H.P.		1,431	1,336
Gross total I.H.P.		2,767	
Coal per I.H.P., pounds		1.84	
Speed, knots		11.4	

It will be noticed that the coal consumption is 1.84 pounds per indicated horsepower. It should be mentioned, however, that the modifications which have been made to the auxiliary exhaust system in several recent ships, with successful results in the matter of coal consumption, could not be carried out on board the *Ocean* without delaying the trials, and it was, therefore, decided that these modifications would be made after the ship was taken over.

The Engineer-in-Chief's Department of the Admiralty was represented on the trial by Mr. Ellis, the machinery being in the charge of Mr. D. C. Beadon, on behalf of Messrs. R. and W. Hawthorn, Leslie & Co.

We are able also to give the following synopsis of the 30-hours' 10,250-I.H.P. trial just completed.

		Starboard.	*Port.*
Mean steam in boilers, pounds		259	258
Mean steam at engines, pounds		221	221
Mean vacuum, inches		27	26.2
Mean revolutions		101.9	103.1
Mean pressure in cylinders,	High, pounds	100.	99.3
	Intermediate, pounds	35.9	35.2
	Low, pounds	12.1	10.9
I.H.P.	High	1,854	1,862
	Intermediate	1,776	1,763
	Low	1,600	1,459
Total I.H.P.		5,230	5,084
Gross total I.H.P.		10,314	
Coal, pounds		1.63	
Speed, knots		16.2	

It will be noticed that the coal consumption is 1.63 pounds per indicated horsepower. This figure is interesting, as it compares exactly with the trials of the vessels of the *Majestic* class at 10,000 horsepower. The coal consumption of those vessels varied from 2 pounds to 2¼ pounds per indicated horsepower, so that on the basis of this comparison, which is a perfectly fair one, a very large saving in coal consumption has been made by the introduction of the Belleville boilers, this being especially marked in steaming at relatively high powers.—"Engineering."

FRANCE.

Jeanne d'Arc.—At last this much talked-of triple-screw armored commerce destroyer has left the ways and is afloat.

The launching took place on June 8th, and was successful. Quite a complete general description of the vessel is given in the JOURNAL, Vol. X, page 864. There seems to be very unusual interest attaching itself to the *Jeanne d'Arc*, both by the English and the French Naval experts, and we quote here part of an article from the "Engineer" on the subject wherein is given some tabular comparative data of the fighting qualities of this vessel with those of the *Terrible* and *Diadem* class of the English Navy.

The further details of the ship and machinery will be given in later issues when they are obtained, and the only dimensions that we will add to the data of the quoted table are that the length of the French cruiser is 447 feet; beam, 63⅝ feet, and draught, 26½ feet.

The comments under the table are also from the "Engineer," and cover several of the points often argued pro and con by the papers of both nations. Of course the results of her trials when finished will be scanned with the deepest interest by all.

.....	*Terrible.*	*Jeanne d'Arc.*	*Diadem.*
Tonnage	14,200	11,270	11,000
Complement	894	626	677
Guns, 1°	two 9.2-inch (B)	two 194 mm. / 7.6-inch (C)	nil
Q. F., 2°	twelve 6-inch (D) / sixteen 3-inch (12-pounders)	fourteen 5.5-in. (D)	sixteen 6 in. (D) / twelve 3-in. (F) / (12-pounders)
Q. F. 3°	twelve 3-pounders	sixteen 3-pdrs. / eight 1-pdr.	twelve 3-pdrs.
Armor:			
On 1° guns	6-inch (C)	6-inch (C)	.....
On 2° guns	6-inch (*c*)	6 inch (C)	4½-inch (*c d*)
Water line	nil	6-inch (*c*)	nil
Lower deck	nil	3-inch (Σ)	nil
Slopes of armor deck in inches, 6 inches equivalent to a protection of	= *a a*	3-inch (*c*)	= *b*
Protection to vitals	= *a a*	= *a a*	= *b*
H.P. (max.)	25,000	28,500 (estimated)	18,000
Speed, (max.), knots	22	23 (estimated)	20.8
Screws	2	3	2
Coal (normal), tons	1,500	1,400 + petroleum	1,000
Bunker capacity, tons	3,000	2,000 + petroleum	2,000

Now from this it is evident that the armored water-line and extra speed are the *Jeanne d'Arc's pros*, while the lack of 3-inch guns make her armament comparatively inferior. Before, however, proceeding to carry the comparison further, we will give further details of the French cruiser.

The water-line belt is complete. Probably it will, like French belts generally, be completely under water; indeed, by design it is practically that. Above it, however, the lower deck is protected by 3-inch armor of a resisting value equivalent to the coal-bunkers on the *Powerful's* lower deck. Probably there are bunkers behind that might be full; but as the ship will carry only 1,400 tons normally, while the *Powerful* normally stows nearer 3,000 than her nominal 2,000, the *Powerful* has a superior coal protection. Now the 3-inch armor of the *Jeanne d'Arc* is not thick enough to keep out our 6-inch Lyddite shell, consequently, save for hits at a wide angle, is of little more utility than the unarmored side of the *Powerful*, and trusting, as this ship does, to her coal-bunkers, it is not impossible that her water line will prove in practice quite as safe as the *Jeanne d'Arc's*.

The protective deck of the *Powerful* being thicker, it will be noted that her vitals are as safe as those of the *Jeanne d'Arc*. So, so far as the *Jeanne d'Arc* is concerned, are those of the *Diadem;* the 8-inch guns could never penetrate the *Diadem's* decks, except possibly at the muzzle. The weak point in the *Diadem* and the *Powerful*, the ability of 3-inch guns to destroy their water lines, the *Jeanne d'Arc* is not provided to cope with. The entire bow of the *Jeanne d'Arc* is covered with 3-inch armor, some protection to the base of the forward 7.6-inch guns, but again too thin to keep out shell, except at very long range and at an acute angle. She would have to fight at long range to avail herself of it, and then the absolutely unprotected bases of her 6-inch guns would give trouble. The *Powerful* has casements or bunkers under her 6-inch guns, and, being a heavier ship with less armor to carry, she is presumably of stouter construction to withstand shell under the guns.

As originally designed the *Jeanne d'Arc* was to have eight instead of fourteen 5.5-inch guns, and twelve 3.9-inch. These

twelve would have been carried where the six upper-deck 5.5-inch pieces are, that is to say, eight in caves about the forward group of funnels, and four aft in gun houses of a kind. It was concluded that these 3.9-inch pieces would be of little use, so every other one was knocked out and 5.5-inch guns substituted. This had the additional advantage of simplifying the armament, an important thing, seeing that how to supply the guns has been a tremendous problem even with the simpler armament.

Progress of Work on New Vessels.—The following new ships will be ready for service during 1900. The first named (*Charlemagne*) will probably be commissioned before the beginning of that year:

Battleships *Charlemagne*, *Saint Louis*, *Gaulois* and *Iéna*.

Third-class cruiser *d'Estrées*.

Torpedo gunboats *Dunois* and *Lahire*.

Gunboats *Décidée* and *Zélée*.

Submarine boat *Narval*.

Torpedo boats *225* and *226*.

Seagoing torpedo boats *Lansquenet* and *Cyclone*.

Also about twenty torpedo destroyers and squadron torpedo boats.

Submarine Boats.—"Le Yacht" states that four submarine boats of the *Narval* type are to be built this year at Rochefort, in addition to those building at Havre and Cherbourg. The same paper states that orders have been received at Rochefort to put in hand four torpedo-boat destroyers of the type of the *Fauconneau*, of which the plans are due to M. Normand. They are are to bear the names of *Pertuisane*, *Escopette*, *Flamberge* and *Rapière*. Their length will be 56 meters and their displacement 303 tons. They will each carry one 6.5-centimeter quick-firing gun, six 4.7-centimeter quick-firing guns, and two torpedo tubes. With 38 tons of coal they are expected to run 2,300 miles at 10 knots, or 220 miles at their full speed of 26 knots.

Suffren.—This battleship, of the improved *Iena* class, was successfully launched at Brest last month.

Henri IV.—This battleship is nearing completion at Cherbourg, and has some peculiar features worthy of notice. She

has usually been considered of the monitor type, save that the main deck proper has only the slight free board of 1.4 meters forward and 80 centimeters aft. There is, however, a superstructure of three-deck height forward of the after turret, the low main deck alone appearing abaft of this turret.

The triple-screw system of propulsion is adopted, and the novelty of two rudders, one between the center screw and each wing screw, is noted. The center screw projects a long way aft from the stern post, and is supported by a heavy steel cylindrical casting, which also carries lugs for stepping the rudders. The wing propellers are 4.5 meters from the center one (center to center).

Dimensions: Displacement, 8,948 tons; length, 108 meters; beam, 22.2 meters; maximum draught aft, 7 meters; horsepower, 11,500.

Triple-expansion engines (vertical) and Niclausse boilers; normal coal capacity, 725 tons; maximum coal capacity, 1,100 tons.

Complement, 26 officers and 438 men.

Jurien de la Gravière was launched at Lorient on the 26th of June in the presence of 10,000 spectators. Her dimensions are: Length, 449 feet; beam, 50 feet; horsepower (designed), 17,400.

She is a triple-screw ship with a normal coal capacity of 600 tons and a maximum of 900 tons, giving a radius of action of 6,150 and 9,300 knots repectively. At 10 knots and at full speed, 880 and 1,330 knots. Her armament will comprise eight 6.4-inch, two 2.5-inch, ten 1.75-inch, and ten 1.5-inch quick-fire guns; also, two underwater torpedo tubes.

GERMANY.

Kaiser Wilhelm der Grosse.—This first-class battleship was successfully launched at Kiel, on June 1, and was the occasion of quite a characteristic christening speech by the German Emperor.

ITALY.

Progress of Work on New Ships.—Orders have been given directing that the armored cruisers *Am. di Saint Bon* and *Emanuele Filiberto*, of 9,800 tons displacement, 13,500 I.H.P. and 18

knots speed, being built at Venice and Castellamare, shall be completed and equipped by the end of the year, and that the cruiser *Puglia*, of 2,550 tons, 7,000 horsepower and 18 knots, shall be entirely ready at Tarento by the end of 1900. The arsenal of Tarento just commenced the cruiser of the second class, *Basilicata*. The little cruisers, *Agordat* and *Coatit*, of 1,313 tons, 7,500 horsepower and 22 knots, ought to be launched at Castellamare in the present month of June.

Garibaldi.—This new armored cruiser, with an old name, was launched June 29th at Sestri Ponente, at the Ansaldo works. She is larger than the preceding cruiser of the same name, which was sold, being of 7,400 tons against 6,900 tons. Her protection and armament places her in the rank of formidable vessels.

JAPAN.

Sazanami.—On Thursday, July the 20th, the official trial took place of the *Sazanami*, the fourth Japanese torpedo-boat destroyer constructed by Messrs. Yarrow and Co., and as this trial is somewhat exceptional as regards the high speed combined with the low air pressure, we give particulars of it below. The vessel, we may state, was launched on Saturday, July the 8th. Load carried, 35 tons; duration of trial, three hours; coal burnt during the three-hours' trial, 15½ tons. The following figures were obtained on the measured mile:

Hour.	Air.	Mean revolutions.	Time.	Speed.	Mean.	Second mean.	Mean on miles.
	in.		*min. sec.*				*knots.*
11.24	0.82	381.4	2 3	29.268			
					30.850		
11.34	1.06	389.2	1 51	32.432		30.910	
					30.970		
11.43	1.10	390.5	2 2	29.508		31.119	
					31.268		31.183
11.53	1.25	390.6	1 49	33.027		31.298	
					31.328		
12.2	1.20	395.3	2 1½	29.629		31.405	
					31.481		
12.11	1.18	390.5	1 48	33.333			
Means,	1⅛	389.6	.....	.....	.....	.....	.....

The boiler pressure was 230 pounds per square inch, and the vacuum average 24¾ inches of mercury. Mean revolutions for the three hours was 392.09, equivalent to a mean speed during this time of 31.382 knots, and the mean air pressure was 1⅛ inches.

Akebono.—The torpedo-boat destroyer *Akebono* (meaning "Dawn"), built by Messrs. Yarrow for the Japanese Government, is the third of six similar destroyers ordered by Japan, two of which have already been delivered, and three are still to be launched. The *Akebono* has a bunker capacity of fully 100 tons. The vessel is built of galvanized steel alloyed with nickel, the tensile strength being about 40 tons per square inch. This material has been selected on account of its successful adoption in the torpedo-boat destroyer *Sokol*, which was built about four years since by Messrs. Yarrow and Co. for the Russian Government. The *Akebono* is 220 feet in length, 20 feet 6 inches in breadth, and carries an armament of one 12-pounder and five 6-pounder quick-firing guns, besides two 18-inch swivel torpedo tubes. The propelling machinery consists of twin screws actuated by two sets of four-cylinder triple-expansion engines having cylinders 20½ inches, 31 inches, and two of 34 inches diameter with an 18-inch stroke. The engines are designed in conformity with the Yarrow, Schlick and Tweedy system. The machinery is supplied with steam at 230 pounds pressure by four Yarrow straight-tube water-tube boilers. These boilers are the largest hitherto constructed of this type, and they each indicate 1,600 H.P., and weigh 18 tons, including water and all fittings. The *Akebono* was launched on April 24th, and at the official trial on the three-hours' run, with a draught 5 feet forward and 9 feet aft, and a load of 35 tons, attained a mean speed of 31.159 knots, with a pressure of 226 pounds of steam.

RUSSIA.

Gromoboy.—This armored cruiser, of the modified *Rossia* type, was launched May 20th, just one year from the time she was put on the stocks. She has a complete armor belt and the

hull is sheathed with wood and copper. This is also an addition to the now large fleet of the world's triple-screw warships.

The *Gromoboy* has the following dimensions: Length, 146.3 meters; beam, 21 meters; draught, 7.92 meters; displacement, 12,360 tons.

The original idea was to install 36 Belleville boilers with economizers, but the machinery data will be published when the vessel is nearer completion and details all decided.

The estimated horsepower is 14,500—intended to give at least 20 knots speed.

MERCHANT STEAMERS.

A New Plant Liner.—Characteristic features of a vessel building for the Plant system by the Wm. Cramp & Sons Co., of Philadelphia, are such as to place her in the front rank of her class. She is intended for coastwise traffic, and is designed to have on a draught of only 18 feet, a cargo capacity of 3,800 tons, and to attain with cargo a speed of 18 knots. This speed is guaranteed on a long-distance loaded trial of a very complete character, much more thorough, indeed, than Government tests, inasmuch as it comprises a requirement of performance on a fixed total quantity of coal.

Dimensions of this new steamer are: Length between perpendiculars, 400 feet; beam, 50 feet; molded depth, 36½ feet; making her one of the largest of her class. The hull will be provided with double bottom, and will be divided into nine compartments by eight watertight bulkheads carried without any openings up to the under side of the main deck. One of these bulkheads divides the boiler room and coal bunkers into two parts, thus reducing the risk of crippling the steam power. Bilge keels of unusual proportions, and a fender for docking, are provided. This vessel will, of course, be classed as an auxiliary cruiser and will enter a trial for classification under the provisions of the postal subsidy act.

Accommodations of a liberal character are provided for 350 first-class and for 100 second-class passengers. These include 100 staterooms, 8 feet deep, opening out on the upper decks. All the first-class accommodations are above the main deck. A handsome saloon to seat 140 persons is on the upper deck, with a ladies' saloon and a smoking room forward, with the purser's office conveniently accessible; also, toilets readily reached, and all under cover. The saloons are lighted and ventilated by a central trunk skylight, 7 feet wide. In the saloon a novel feature

will be separate tables for parties of four, and in the music room a grand piano will be placed, enabling a singer to face the audience. The upper deck affords a sheltered promenade the full length of the ship of not less than 8 feet width on each quarter, and the awning deck above is 340 feet in length and of not less than 10 feet width, with an extension forward around the foremast, affording to passengers a clear view ahead. On this deck the boats are usually placed, but in this new vessel they will be overhead, and some improvements in arrangements for launching will add to the security of passengers. The engine and boiler-room casings are carried up above this deck to the bridge head, as well as the galley vent, thus freeing passengers from the smells incident to the location of such vents on deck. There are two bridges, one forward and one aft, with two systems of steering, whereby this large vessel can be maneuvered in and out of troublesome channels. Much attention has been directed to the sanitary appliances, which are probably more elaborate than anything heretofore afforded.

Arrangements for rapid handling of cargo comprise five elevators reached by side ports, and a quick-acting winch at forward hatch. Coaling will be effected by a newly-designed apparatus capable of coaling the ship within two hours, a task worthy of note, as she carries five days' supply for full speed of 18 knots, or nine days' supply at reduced speed. Ashes and garbage are dumped directly overboard. A large mail room is provided, with mail doors starboard and port, and with apparatus to deliver and receive mail bags to and from small boats. The vessel will be propelled by twin screws operated by triple-expansion four-cylinder engines. She is to be fitted with two pole masts, carrying leg-of-mutton sails and staysails, and will have two funnels.

Ponce.—The Harlan & Hollingsworth Co. launched, July 22, the new freight and passenger steamer for the New York & Porto Rico Steamship Co., *Ponce*. The *Ponce* is 335 feet over all, 317 feet between perpendiculars, 322 feet on water line, 42 feet beam, and of 19 feet load draught. Other particulars of this vessel are: Deadweight carrying capacity, 3,250 tons; six water-tight

bulkheads; four winches; two steel masts; deck house of steel; accommodations for seventy-two first-class and twenty second-class passengers; double electric-lighting plant with 232 lights; evaporator with a capacity of 15 tons; five water tanks of 8,000 gallons capacity; engines of direct, tri-compound type with inverted cylinders, 24, 38 and 62 inches diameter and 42 inches stroke; speed, 12 knots; single screw; two steel Scotch boilers, 14 feet 6 inches diameter and 11 feet long, with six furnaces of 48 inches diameter; boiler pressure, 180 pounds; Ellis & Eaves' induced draft; bunker capacity, 350 tons.

Inchkeith.—This screw steamer had its official trial trip on July 8th. The vessel is noteworthy as being the second steamer in which has been fitted a set of Mudd's patent five-crank quadruple-expansion machinery by the Central Marine Engine Works, West Hartlepool. This new departure in marine engine building was taken by the late Mr. Mudd, the first set being fitted in the screw steamer *Inchmona*. The object in the design of these engines and boilers is the attainment of further economy in coal consumption, and the results obtained in the *Inchmona* have fully justified the anticipations of the builders. The *Inchmona* is claimed to be the most economical steamer afloat, the consumption of coal per I.H.P. per hour in that steamer not having averaged more than 1.15 pounds over the whole period during which the vessel has been at sea, viz: since May, 1896. This reduced coal consumption gives larger available capacity for cargo carrying, which means both increase of earnings and decrease of outgoings. The *Inchkeith* is of the following dimensions: Length, 348 feet; breadth, 47 feet; depth, 28 feet 1½ inches, and a deadweight capacity of 6,600 tons on 22 feet 5-inches draught, which is somewhat more than that of the *Inchmona*. The water-ballast capacity is 1,287 tons. The engines are of the same size as those fitted in the *Inchmona*, viz: 17 inches, 24 inches, 34 inches, and two of 42 inches diameter, with a piston stroke of 42 inches. The boilers are of the ordinary cylindrical multitubular type, built for a working pressure of 260 pounds per square inch, and adapted to work with Ellis and Eaves' type of induced draft. In addition to the main feed

pumps on the engines a pair of Weir's pumps are fitted. The trial was in every way satisfactory, and a speed of over 11½ knots being averaged.—"Engineer's Gazette."

Ortona.—Messrs. Vickers, Sons & Maxim, Limited, launched at Barrow, on July 10, the *Ortona*, a large twin-screw steamer for the Australian mail and passenger service of the Pacific Steam Navigation Company. The steamer is 500 feet long, 55 feet beam and 37 feet molded depth to upper deck, the gross tonnage being 7,600 tons. There are three complete closed-in decks, and accommodation is provided for 130 first, 162 second-class and 300 steerage passengers. The machinery has been designed to give the vessel an average speed at sea when fully laden of 15½ knots.

Montezuma. — Messrs. Alex. Stephen & Sons, Glasgow, launched, on July 11, the twin-screw steamer *Montezuma*, of 490 feet over all and 59 feet beam, with shelter deck fore and aft and upper bridge, built to the order of Messrs. Elder, Dempster & Co., Liverpool.

Wilcannia.—This screw steamer had its official trial trip on July 11th. She is the sixth vessel built by the Sunderland Shipbuilding Company, Limited, to the order of W. Lund, Esq., London. The principal dimensions are: Length, 400 feet; breadth, 48 feet; depth molded, 31 feet 3 inches; and a carrying capacity of 6,000 tons. The vessel has been specially designed for the owner's line, running between London and Australia, and has accommodation for fifty first-class and fifty third-class passengers. The whole of the forehold and fore 'tween decks have been insulated for the carrying of frozen meat. The main engines are by The North Eastern Marine Engineering Company, Limited, Wallsend-on-Tyne, the cylinders being 28 inches, 47 inches, and 78 inches, by 54 inches stroke, with bronze propeller, steam being supplied by four single-ended boilers working at a pressure of 180 pounds, and they are fitted with Howden's patent forced draft. During the trial the whole of the machinery worked with the greatest satisfaction, a mean speed of 13¼ knots being maintained.

Star of Australia.—On Saturday morning, June 24, there was launched from the North Yard of Messrs. Workman, Clark

& Co., Limited, a large steel screw steamer named the *Star of Australia*, built to the order of Messrs. J. P. Corry & Co., London. The leading dimensions are: Length, 440 feet; breadth molded, 55 feet; depth molded, 33 feet; with a gross tonnage of 7,370 tons. There are five cargo holds, and as this vessel is chiefly intended for the Australian and New Zealand trade, three of these are insulated for carrying frozen meat.

YACHTS.

Royal Yacht Machinery.—The machinery installation in the royal yacht *Victoria and Albert*, which was recently launched at Pembroke dock yard (see issue of "Review," May 25, 1899, for description of the vessel), is very completely described in "Engineering," of London. Engines and boilers are arranged in four water-tight compartments, the engines being in two, side by side, and the boilers in two, one before the other. The two sets of machinery will develop 11,000 indicated horsepower for eight hours and 7,500 indicated horsepower continuously. The pressure of steam in the boilers will be 300 pounds per square inch, lowered by a reducing valve to 250 pounds at the engines. The engines are of the vertical, four-cylinder, triple-expansion description. The high-pressure cylinder is on the forward side of the intermediate, and these two are between two low-pressure cylinders. The slide valves are of the piston type for the high and intermediate cylinders, and flat valves, with relief rings on the back, are fitted to the low-pressure cylinders. The valves are so set that one-third of the power may be developed in the high-pressure cylinders, one-third in the intermediate and one-third in the combined low-pressure cylinders. The piston and connecting, rods, bearings, etc., are similarly proportioned. In order to make the crank shafts interchangeable the crank pins are all of the same diameter, their lengths being proportioned to give the required surfaces. The cranks are arranged at such angles as will keep the engines free from vibration.

The high-pressure cylinders are 26½ inches, the intermediate 44½ inches and the low-pressure cylinders 53 inches in diameter, with a stroke 3 feet 3 inches. The revolutions for the maximum power will be 140 per minute. The high and intermediate-pressure cylinders are fitted with piston valves, and the low-pressure with flat valves with large relief rings. The valves

are each worked by double eccentrics and a single solid-bar link. The crank shafts are in two pieces, 14½ inches external and 8¾ inches internal diameter. The crank pins are 15½ inches external and 8½ inches internal diameter, their lengths being 20 inches for the high and intermediate-pressure cylinders, and 13 inches for the low-pressure. The engines are reversed by steam as well as by hand. The reversing engines each have two cylinders 5½ inches in diameter and 6 inches stroke, and make about 130 revolutions in putting the link over from ahead to astern by means of a direct-acting double-threaded screw. To prevent any material amount of racing, each set of main engines is provided with an Aspinall's patent governor, which actuates a throttle valve fitted in the steam pipe close to the regulating valve. A lever is fitted to the back column of the high-pressure cylinder, to which the governor is attached, and this is designed to prevent the engines exceeding their normal revolutions by more than 5 per cent. The steam pipe from the forward boiler room is connected to the starboard engines, and that from the after boilers to the port engines, with a connection in the engine room. Separators with automatic and hand blow-off arrangements are fitted in the after boiler room to these pipes. There are two condensers in each engine room with the requisite connections for working the main engine when either condenser is shut off. This provision is made so that in the event of leakage occurring, the condenser may be disconnected and the defect remedied without stopping the engines. These condensers are placed horizontally, and the water circulates outside the tubes. The tube-cooling surface is 12,000 square feet, or a little less than 1.1 square feet per indicated horsepower. The tubes are ⅝ inches external diameter, secured to the plates by screwed glands and tape packing. The air pumps, 11¼ inches in diameter, are worked directly from each low-pressure piston, and under normal conditions each draws from its own condenser, but means are fitted for supplying each air pump with water to prevent overheating when the corresponding condenser is not in use.

One circulating pump is provided in each engine room, and a

connection is made through the middle-line bulkhead to allow of either pump supplying all the condensers. The impellers are 45 inches in diameter, and the sea-suction and discharge pipes 16 inches. The usual provision is made for these pumps to draw from the bilge. There are four fire and bilge pumps, each capable of delivering 60 tons of water per hour. These, with the two circulating engines, will, if required, pump about 2,300 tons of water per hour from the bilge. A patent "gravitation" feed-water heater is fitted in each engine room, through which the air pumps deliver into the feed tanks. A vertical auxiliary condenser, with 800 square feet of cooling surface, and a combined circulating and air pump are provided in each engine. A turning engine with two cylinders, 4½ inches in diameter and 5 inches stroke, is fitted in each engine room to move the main engines through one revolution in not more than eight minutes. Provision is also made for turning the engines by hand.

The screw propellers are arranged to work inwards when the vessel is steaming ahead. Each boss is fitted with three adjustable blades. The propellers are of ordinary gun metal, the blades being secured to the boss by bolts of forged bronze. The diameter of the propellers is 13 feet 3 inches. The blades are set at a pitch of 17 feet 6 inches, and have an expanded surface of 12 square feet for each propeller. Duplicate steering engines, by Messrs. Caldwell & Co., Glasgow, are arranged one in each engine room, with shafting, etc., for working them from the bridge. The worms, which are below their wheels, work in an oil bath. At the after end of each engine room, close to the cool chamber, there is a refrigerating machine. Each machine is capable of keeping a chamber of 2,500 cubic feet at a temperature of 15 degrees in the tropics, and of keeping the atmosphere in the chamber dry. There are three sets of electric-light engines with dynamos, each set being of 600 ampères. To assist in ventilating the engine rooms there are four blowing fans, one at each end of each engine room. The main cylinders are clothed on their sides, bottoms and covers with mica. This is covered with polished mahogany secured by burnished brass strips. The flanges are covered with a planished-steel casing fitted in port-

able sections, so that it may be readily removed. Asbestos cloth is fitted under the attachments of the mahogany and the steel.

The boilers are of the Belleville type, and the safety valves are loaded by springs to 300 pounds per square inch. In the forward compartment there are six boilers, each containing eight generator and seven economizer elements, and three with ten generator and eight economizer elements. In the after compartment there are nine boilers, each with ten generator and eight economizer elements. The generator and economizer tubes are 4 inches and 2¾ inches in diameter respectively. The total heating surface is 26,000 square feet, or about 2.35 feet per indicated horsepower, and the grate surface is 840 square feet, which will give about 13 indicated horsepower per square foot. The feed pumps, which are of the Belleville, vertical, direct-acting description, are in the boiler rooms, there being two main and two auxiliary, each about 11½ inches in diameter and 19¾ inches stroke. In each boiler compartment there is one double-cylinder and one single-cylinder engine for delivering jets of air above the fires and into the combustion chambers to assist in mingling the gases. The boilers are to work under natural-draft conditions, but fans are provided to insure a plentiful supply of air to the stokeholds under all conditions of wind. Four See ash ejectors, with two pumping engines, are provided for discharging the ashes through the sides of the vessel, and there are two ordinary ash tubes and engines for use in harbor.

Nixon's Steam Yacht.—There is now under construction at Lewis Nixon's Crescent Ship Yard, Elizabethport, N. J., a most interesting craft—a steam yacht designed in accordance with the general model of gunboats of the *Annapolis* class, and which is an almost exact duplicate of the *Pathfinder*. This steam yacht is being built on a commission from J. Harvey Ladew, and is designed to replace the yacht *Columbia*, which he sold to the United States Government during the Spanish-American war. This new yacht is, as far as known, the only one in which any regard has been given to the suggestion made since the close of the war that hereafter steam yachts be built with some reference to the possibility of their conversion into auxiliary gunboats. Plans of the

Ladew yacht were submitted to the Navy Department in order that any suggestions relative to the necessity for stability of construction, were armament to be placed aboard, might be carried out. The same plan was followed as regards interior arrangements, even in the matter of engines.

The Ladew yacht is 200 feet over all, 165 feet on the water line, 33 feet 6 inches beam and 11 feet draught. She will be fitted with triple-expansion engines with cylinders of 18, 27 and 45 inches diameter and 28 inches stroke. Steam will be supplied from two Scotch boilers. It is estimated that her speed will be 14½ knots, and with coal-bunker capacity of 250 tons she will be enabled to steam fully 7,000 miles.

The yacht, which will be brigantine rigged and have a large sail spread, will have double decks, the living quarters being located on the main and berth decks. On the main deck will be a house for the pilot with a bridge on top. The arrangement of the various apartments is in many respects admirable. Each of the five suites will consist of a bed room, sitting room and bath. The main saloon will be 16 by 32 feet; the dining saloon is 18 by 30 feet; a large stateroom 14 by 24 feet extending the full width of the ship, together with pantries, galley and officers' rooms. A handsome library will be a feature of the vessel. Aft there will be eight guests' rooms on the berth deck, two bath rooms and a room with accommodations for four maids. A party of twenty-five can be carried on the yacht with entire comfort. The vessel has an elaborate system of watertight compartments, together with plated decks and watertight hatches.

ASSOCIATION NOTES.

Another honor to the Engineer-in-Chief, and one which naval engineers unite in deeming most appropriate and deserved, was conferred by the Columbia University of New York, in the form of the Honorary Degree of Master of Science, at the Commencement exercises of that institution, June 7, 1899. Professor F. R. Hutton, head of the Department of Mechanical Engineering of the University, introduced the Admiral in the following characteristic speech, which we are pleased to record in full:

Mr. President: I am to present to you Rear Admiral George W. Melville, Engineer-in-Chief of the United States Navy, who has been named by the Trustees for the Honorary Degree of Master of Science. It is significant that this degree is given today for the first time in the history of the University, and that its award should be to one to whom the honor is so singularly fitting.

I present to you Admiral Melville as a Master of Science, both in that field where knowledge for its own sake is its own exceeding great reward and also in that where the Mechanical Engineer leaves the impress of his thought and creative energy upon concrete achievements in iron and steel.

I bring you, sir, one who has made himself, in the first place, an authority and expert upon Arctic exploration. This knowledge has been acquired in service as an officer, first upon the *Tigress*, in the search for a part of the crew of the *Polaris*, later as an Engineer officer of the *Jeannette*, under Lieutenant De Long, and finally with the relief party which went to rescue Greely with the *Thetis* and the *Bear*. It would be impossible to refrain from a reference to the revelations of personal quality which belong to the experience of these years, and yet only a permitted hand should lift the veil from the tragedies which it conceals. I speak only with bated breadth of the imprisoned *Jeannette*, with her

frames cracking under the remorseless grip of the ice pack; of the terrible journey across the floes to the launching in the icy sea; of the long exposure to the Arctic gale in open boat, which left its impress on arms and feet, frozen to disablement from exposure; of the lonely landing upon an island of the Lena Delta in Siberia; of the unfaltering prosecution of a search for comrades, when even hardy natives were cowed by the warring elements; of the heartbreaking end of the search when only the dead were found in their last bivouac; of the lonely burial on the shores of the unfriendly sea. These, sir, are memories to thrill under and not to recount lightly.

But I turn rather to the achievements of Admiral Melville in that other field where as a mechanical engineer he has impressed himself upon the engineering of the Navy of our country. Melville is now serving as Engineer-in-Chief of the United States Navy for his third term. When he was appointed in 1888 the only modern vessels in commission were the *Atlanta*, the *Boston* and the *Dolphin*—two cruisers and a dispatch boat. The twelve years of his service have enabled him as Bureau Chief to be responsible for the design and engining of one hundred and twenty ships, aggregating 700,000 horsepower. Beginning with the *San Francisco*, the earliest American-designed vessel of our modern Navy, his sound mechanical judgment, his boldness and his progressiveness have culminated in the *Columbia* and the *Minneapolis*, each triple-screw giants, each holding for a time the world's record for speed.

But, sir, lest I weary with technical detail, I pass to a final reference to that upon which Columbia to-day bases her meed of praise. I refer, sir, to the significance in the war of 1898, which belongs to the preparation and the achievments of the Navy in the Spanish-American conflict. The conception of a floating machine shop, whereby vessels could be outfitted and repaired a thousand miles from a shore basis and a navy yard, and the development of economical distilling ships, whereby a large body of men and vessels on blockade could be supplied with fresh water without the necessity of touching a hostile shore, and the condition of the engineering departments of our

vessels when the hour of battle had struck, give Admiral Melville's leadership a significance which we are glad to honor. It must not be forgotten, sir, that the achievements of the captains of our fleet are the result, in great part, of the thought, the planning and the capacity of those engineers who gave them their weapons and who operated for them the battle machines with which their work was done.

Sir, I present you Rear Admiral George W. Melville.

At a special meeting of the Council, held August 15, the votes on the proposed change in Article 5 of the By-laws, as noted in the May JOURNAL and also by special cards, were counted, with the result of an almost unanimous assent to the change. One hundred and twenty-three votes were received, of which five only were against the change. The By-laws are herein reprinted as modified in conformity with this vote. See last pages of this issue.

We are in receipt of many inquiries as to the propriety and prospects of retaining the individuality of the American Society of Naval Engineers, now that the Personnel Bill has removed the name of Engineer Corps from the Navy Lists. The inquiries are not unnatural, but imply a misunderstanding of the spirit of the Bill. The Naval Engineer not only exists in the American Navy to-day as distinctly as he ever did, but the whole tenor of the Personnel Bill is to expand the number of Engineers by the addition of all the Line Officers. Eventually this must be the result, as essentially the modern naval officer must be an engineer. There is no diminution of interest in engineering by those who formerly were in the Engineer Corps, and there is no reason for imagining any waning of this interest. There is no profession which is advancing more rapidly, scientifically, than Naval Engineering. Its work approaches that of an exact science, in which generalities are replaced by positive facts and unimpeachable data. Continuous observation and study is the price of the retention of a position even in the rear ranks of the on-

marching body of the profession, and this Society, with its name and purpose unchanged, will continue to hold a most important place in the Engineering world. If the members will more fully realize this, and lend assistance in furnishing important professional matter for the pages of the JOURNAL, their work will be in line with a right and proper appreciation of the spirit of the Personnel Bill, and also that of the By-laws of the Society.

There is a marked appreciation of the JOURNAL in the Engineering world outside of naval circles, as well as the continued interest within, and a steadily increasing prosperity is encouragement for continuance in the separate and distinct form so long our own, and for the belief that it would be poor policy indeed to in any way unite with other societies of even nearly kindred professions when there is such a growing field of usefulness in the specialties of Naval Engineering.

Article 22 of the By-laws directs that nominations shall be considered at the regular meeting on the first Tuesday in October of each year. While usually most of the nominations are made by members residing in Washington, it is not necessary that this should be so. Any member, wherever stationed, who desires to secure consideration of a particular nomination should submit the same, in conformity with the By-laws, before the October meeting. The nominations should be made separately for President, Secretary-Treasurer, and for three members of Council.

BY-LAWS OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

1. The Association shall be known as the AMERICAN SOCIETY OF NAVAL ENGINEERS.

2. The object of the Society shall be to promote a knowledge of marine engineering and naval architecture by reading, discussing and publishing papers on professional subjects; by bringing together the results of experience acquired by engineers in all parts of the world, which, though valueless when unconnected, tend much to the advancement of engineering when published together in the JOURNAL of the Society; by publishing the results of such experimental and other inquiries as may be deemed essential to the advancement of the science; and historical events in the lives of engineers.

3. The officers of the Society shall be a President, a Secretary-Treasurer, and a Council, all of whom shall be elected annually.

4. The Society shall be composed of Members, Associates and Honorary Members.

5. Officers of the Line and Construction Corps, and ex-officers of the Engineer, Line and Construction Corps of the Navy, and officers and ex-officers of the Revenue Cutter Service shall be eligible as Members.

6. Persons in civil life whose knowledge of engineering is such that they can co-operate with naval engineers in the promotion of professional knowledge, or who are intimately connected with the engineering profession, shall be eligible as Associates.

7. The Secretary of the Navy, the Assistant Secretary of the Navy, the Chief of the Bureau of Steam Engineering of the Navy Department, all ex-Chiefs of the Bureau of Steam Engineering, the prize essayist of each year, and such other persons as the Society may elect, shall be Honorary Members.

8. Members shall be admitted upon application and payment of the annual subscription.

9. An Associate may be admitted upon application in writing and payment of the annual subscription, provided his application have the recommendation of a member, and receive the approval of a majority of the Council.

10. Associates shall be entitled to all the privileges of Members except voting and holding office.

11. To be eligible as Honorary Member the candidate must receive the unanimous vote of the Council before his name shall be presented to the Society; and the favorable vote of two-thirds of the Members voting shall be necessary for election.

12. The direction and management of the affairs of the Society, and the editing and publishing of the JOURNAL, shall be vested in a Council composed of five members, the President and the Secretary-Treasurer being members *ex officio*. The Council may appoint one of its number Librarian.

13. The President shall exercise the usual duties of that office.

14. The Secretary-Treasurer shall conduct the correspondence of the Society and its financial transactions. He shall submit an annual statement of the receipts and expenditures of the Society, which shall be audited by three other members of the Council.

15. The Council shall have authority to fill vacancies which may occur during the year.

16. Subscriptions, and all matter intended for publication, shall be sent to the Secretary-Treasurer; but no paper shall be read before the Society at the annual meeting, nor anything published in the JOURNAL, without the approval of the Council.

17. In deciding matters pertaining to the Society, none but members shall be entitled to vote; to constitute a quorum for business, nine members must be present.

18. The Society shall meet annually in the City of Washington, and at such other times and places as meetings can be conveniently arranged.

19. The annual subscription shall be five dollars, payable in advance.

20. Copies of the JOURNAL may be sold by the Society at a price which shall be fixed by the Council.

21. Absent members voting on any proposition, must state

over their signatures whether they are for or against the proposition.

22. On the first Tuesday in October, a meeting of the Society shall be held for the consideration of nominations to offices falling vacant under the rules. Nominations to office must be made in writing, and may be made by any member, whether present at the meeting or not. The consent of the nominee to accept office if elected must be assured. A necessary qualification of all nominees, besides full membership, is residence in or near Washington during the term of office.

23. After the nominations are all made, lists of the candidates for the different offices shall be prepared by the Secretary-Treasurer, and mailed to all Members of the Society. Each voting list must be signed, and must show under the different offices the name of the person voted for. Each voter will enclose his ballot in a sealed envelope, which will be sent to the Secretary-Treasurer previous to the annual meeting. At the annual meeting the envelopes will be opened and the votes counted.

24. Nothing in the preceding section shall preclude the name of any candidate from being put in nomination for more than one office. In case of a tie, the presiding officer shall decide. Voting by proxy is prohibited.

25. In the event of a candidate receiving the greatest number of votes for more than one office, he shall decide which he will accept.

26. Any office falling vacant in the course of the year owing to the death, resignation or removal from Washington or vicinity of the incumbent, shall be filled by vote of the members of the Council remaining.

27. Motions to amend these By-laws, or to make new By-laws, must be in writing, and must lie over at least three months, during which time notice thereof shall be sent to all members; and the assent of two-thirds of the members voting shall be necessary to amend or adopt.

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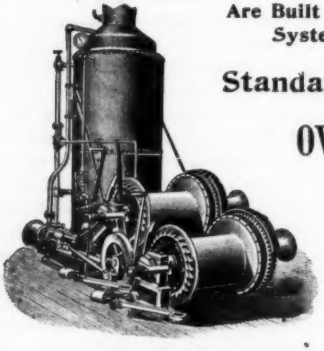

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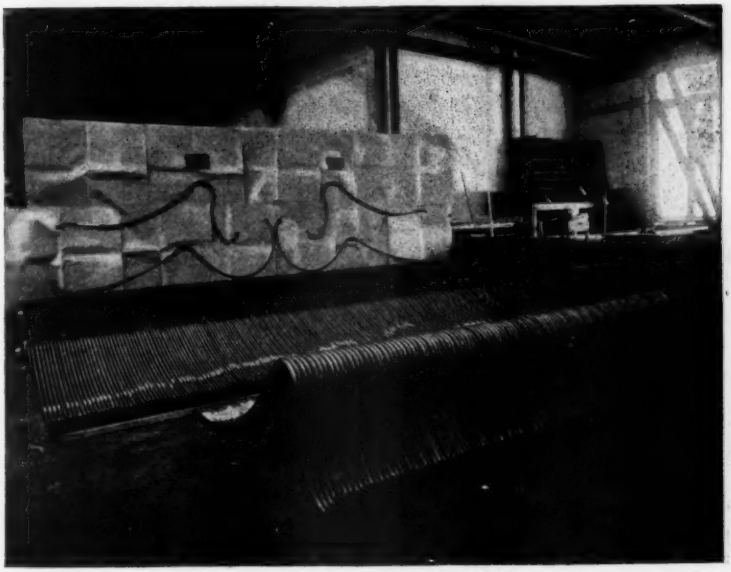

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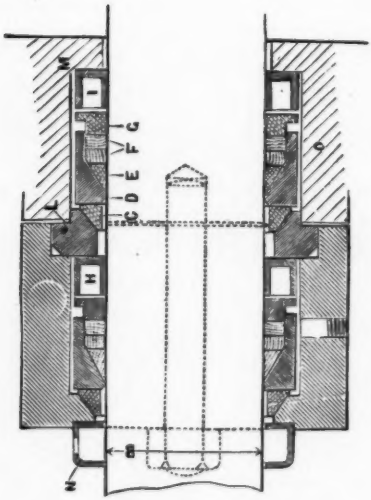

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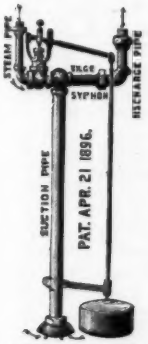

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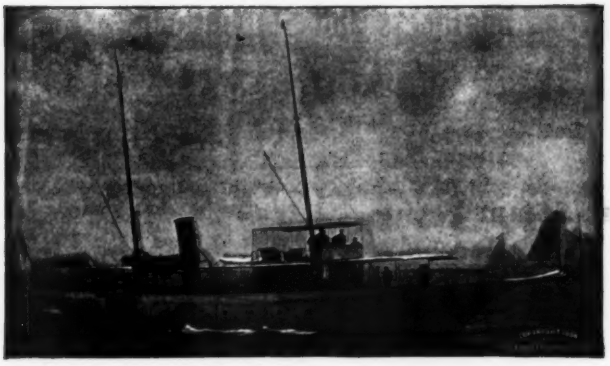

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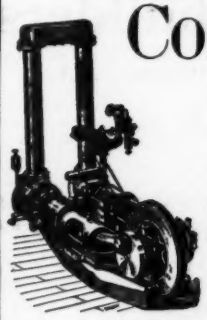

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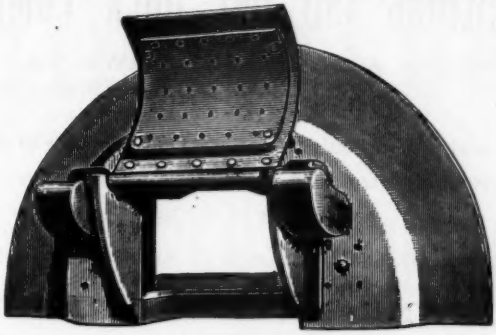

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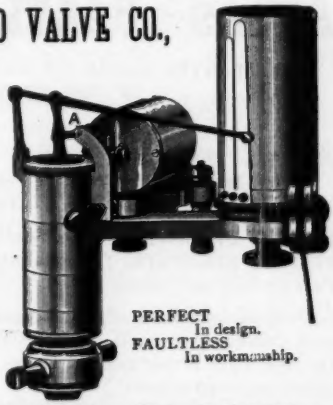

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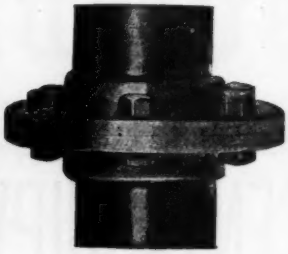
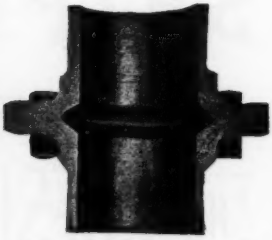


Upset and Flanged.



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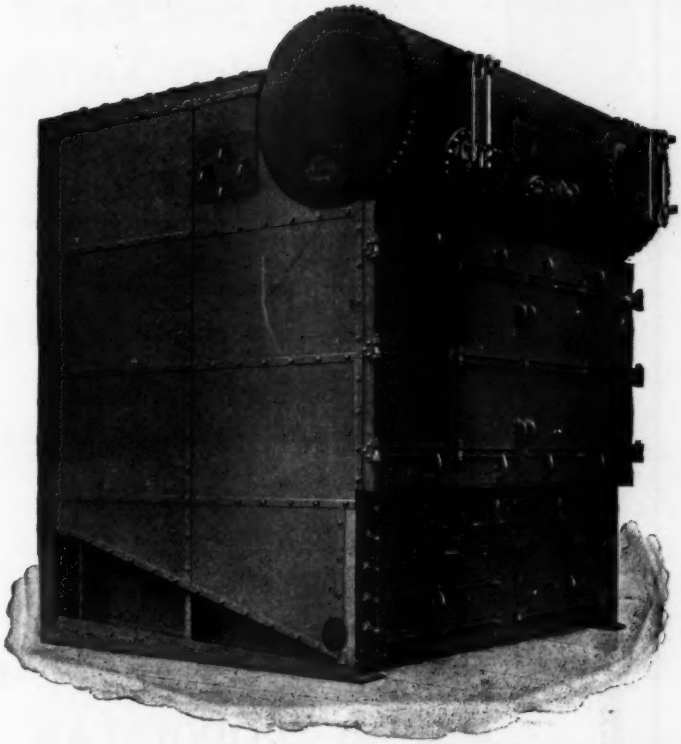

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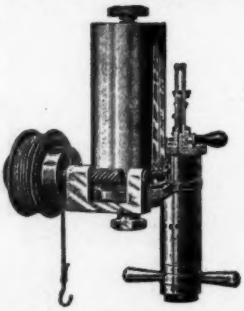

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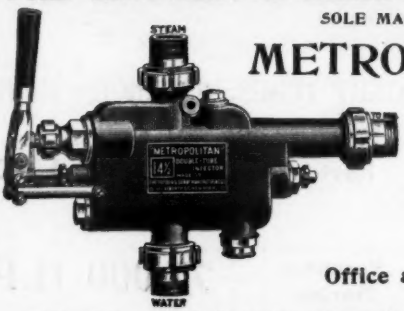

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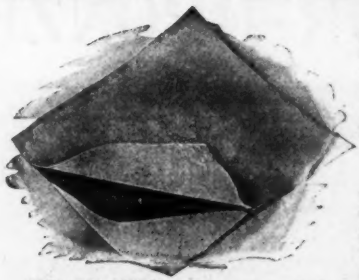

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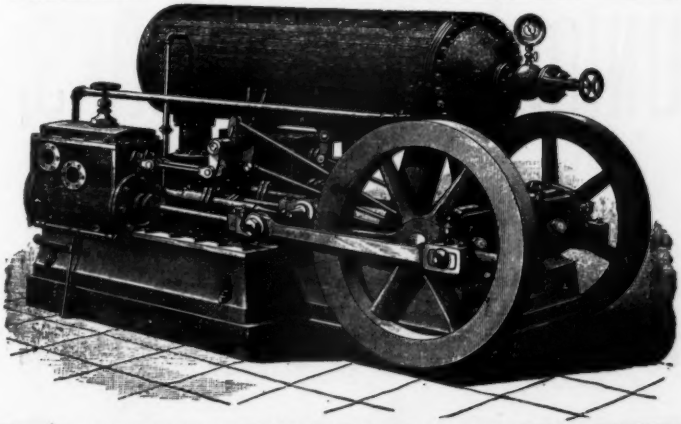

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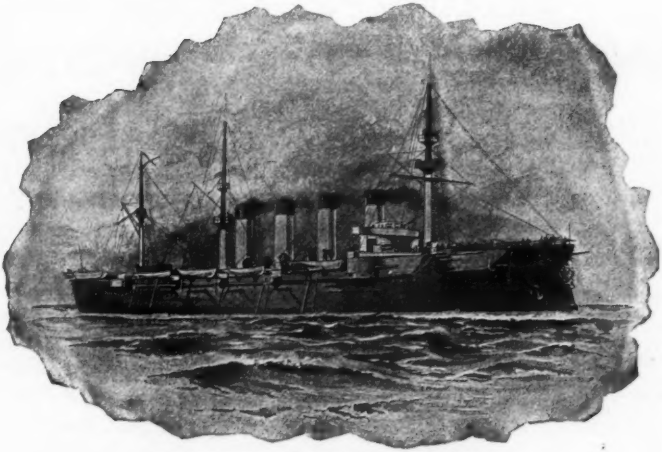

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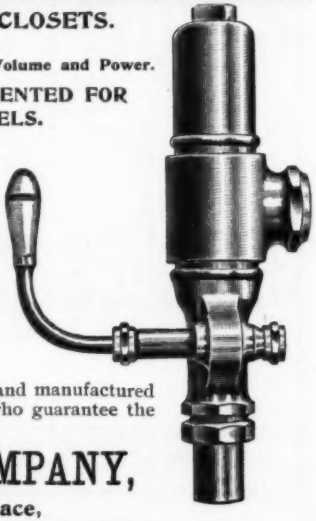

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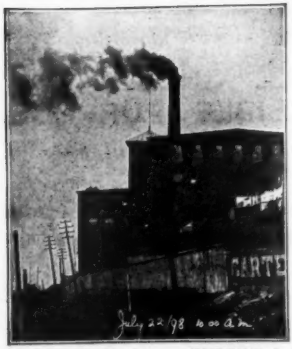

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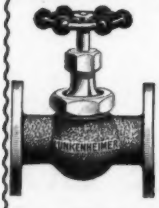

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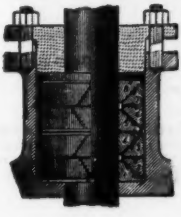

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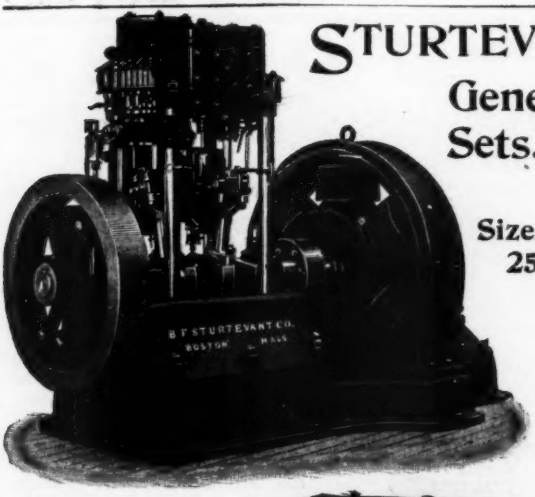

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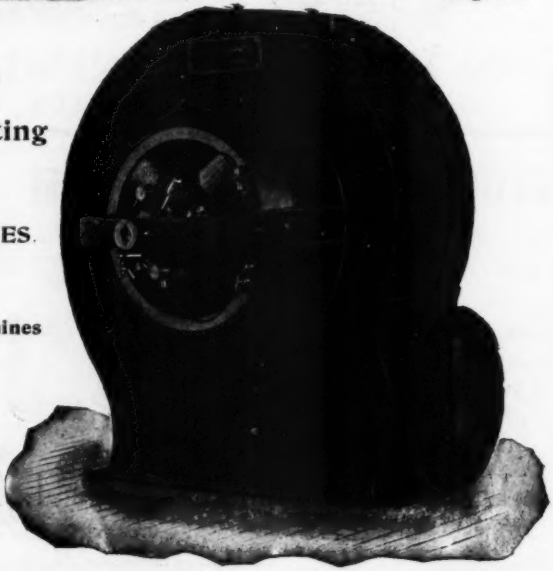

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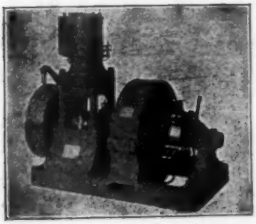

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